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Review Article

Ebola, KFD and Bats

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A B S T R A C T

The headline in the *Times of India*, dated July 23, 2019, **"India Needs to Prepare for Ebola, Other Viral Diseases"** was frightening. It quotes an article in *Indian Journal of Medical Research,* which states "Bats are thought to be the natural reservoirs of this virus…..India is home to a great diversity of bat species…." But Ebola has not yet come to India, though there is every possibility. But what about Kyasanur Forest Disease (KFD), which is already in India and which has links with an insectivorous bat? Recognized in 1957, the virus was isolated in 1969 **over fifty years ago** from four insectivorous bats, *Rhinolophus rouxii,* and from *Ornithodoros* ticks collected from the roosting habitat of these bats, (*Ind. J. Med. Res*, 1969, 905-8). KFD came as a big enough epidemic in 1957, but later petered out and then sporadically appeared throughout the Western Ghat region, from Kerala to Gujarat and an epidemic resurfacing in the oldest theater in January 2019! There were many publications in India about investigations done in these areas, but none of them mentioned anything about bats. The scare of Ebola invading India has now turned the attention of the authorities, after five decades, to bats.

Some of the planet's scariest and most lethal viruses such as the **Ebola** and Rabies find a natural refuge in bats. Several major epidemics around the globe have been known to be caused by bats, and scientists are everyday reporting new viruses thriving on bat population. Linfa Wang of Australian Animal Health Laboratory said the **role of bats is too important to be ignored anymore**. Bats and other animals such as rodents and shrews that chronically harbour viruses, such as that of KFD in India, are therefore, important as disease reservoirs. But we in India have yet to look deep into the role of bats, as a zoonotic reservoir, even though there have been sporadic small outbreaks of KFD in many states in the Western Ghats. Many investigators do go to these spots, collect ticks and specimens from dead monkeys/sick humans, isolate the virus, and publish a paper! As far as I know there is not a single instance where attempts are made to look for the bats which probably are the **zoonotic reservoirs for KFD virus**. I feel that our investigators just do not go deep into the aspects of the source of the virus. *Haemaphysalis* ticks, monkeys and man are not the original source.

Bats had evolved long before humans in the early Eocene period. They act as reservoirs of many viruses, some of them pathogenic to man. They rarely show symptoms of the disease. But **bats are blamed for**

the start of many epidemics. For example, dengue is the most rapidly emerging disease in the tropics. A serologic survey carried out in Sri Lanka indicated that an epizootic dengue virus was active among macaque monkeys. A single epizootic dengue outbreak took place between October 1986 and February 1987, during which 94% of the macaques within the study site were affected. But there is no evidence of any serological survey done in animal hosts such as bats for virus activity in forest areas. There is also sufficient evidence about their role in the natural cycle of Kyasanur Forest Disease **(KFD),** dengue and **Ebola** (Frontline*,* 4 Aug 2017). An epidemic of **Ebola** killed more than 11,000 people in the recent past in West Africa, and scientists believe **"greater long-fingered bat" (*Miniopterus inflates*)**, captured near an abandoned mineshaft in Liberia, is the original source (Kupferschmidt, 2019). This bat which lives in many parts of Africa, roosts in caves and feeds on insects. Scientists had previously found two other Ebola strains in a related insect-eating bat, *M. schreibersii*. Ebola is therefore a virus that has multiple hosts, and it might be regionally dependent as to which species carries it. The finding also sheds new light on the *natural history of Ebola,* which has befuddled scientists for decades (Epstein, a veterinary epidemiologist.

Bats are known to be natural reservoirs for a large number of zoonotic pathogens, including rabies, endemic in many bat populations, histoplasmosis-both directly and in guano, **Nipah** and **Hendra** viruses, and possibly the **Ebola** virus. Bats are hosts and vectors of disease as they are highly mobile; have global distribution, long life and great sympatry (range overlap) and exhibit social behaviour. Compared to rodents, **bats carry more zoonotic viruses per species**, and each virus is shared with more host species. They seem to be highly resistant to most of the viruses they host, *suggesting a degree of adaptation to their immune systems.* Their interactions with domestic animals, including preying and scavenging of bat carcasses complicate the risk of zoonotic transmission. They are implicated in the emergence of Severe Acute Respiratory Syndrome (SARS) in China, since bats (several from a single cave in Yunnan) serve as natural hosts for Corona viruses. Bats host and transmit several disease-causing viruses, to which they themselves are resistant, for example, corona viruses (SARS-CoV and MERS-CoV), filoviruses (Ebola and Marburg), henipaviruses (Nipah and Hendra). As viruses are found in guano, urine, and saliva, epidemic outbreaks may be caused by direct transmission as well. Another area of future research is role of arthropods in causing epidemics by transmission of virus between bats and humans. Despite the shared ecological niches that bats fill with many haematophagous arthropods (e.g., mosquitoes, ticks, biting midges, etc.) known to play a role in the transmission of medically important arboviruses, knowledge surrounding the potential for bats to act as reservoirs for arboviruses is limited (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6466281/).

KFD was first recognized in 1957 in India and has been leap frogging throughout the Western Ghat region off and on. In recent years, several states such as Kerala, Karnataka, Goa and Maharashtra and a small pocket in Nilgiris district of Tamil Nadu have reported human cases of KFD and monkey deaths. Compared with epidemics of KFD during 1957-60, the epidemic was mild. However, the isolation of the virus in bats and their tick parasites should have stimulated interest among researchers, particularly since bats are known to carry many viruses (*Frontline*, August 4, 2017). While studying the natural cycle of the KFD virus, this author had encountered a colony of insectivorous bats, *Rhinolophus rouxii,* in an abandoned well in a remote village, Kasarguppe, in Shivamogga district in 1969. The bats were found infested with a soft tick, a new species called *Ornthodoros (chiropterphila) rhinolophi.* They must have also been feeding on the ticks infesting them in their habitat. KFD virus was isolated from the spleens of four of these bats, and also from *Ornithodoros* ticks collected from the resting site of these bats, from the abandoned well (*Ind. J. Med. Res. 1969*). That bat can be considered reservoirs of arboviruses is also confirmed by the isolation of another new arbovirus, named Muroor virus, from a bat tick *Ornithodoros piriformis* from Shimoga Dist, (Sreenivasan, 1983, *IJMR*, 1983). There are no other published reports of any deliberate searches for these bats made in the area from where KFD virus activity was reported. (When the Rockefeller Foundation withdrew its operations from Poona, may be it is a coincidence, the Virus Research Centre became the National Institute of Virology and the operations were expanded (diluted?) to include study of all viruses. There was no more emphasis on arboviruses and ecology. The entomology division suffered most, with the departure of all top entomologists, and Field Work thereafter became safari research).

Thus, it is well established that the insectivorous bat *Rhinolophus sp* and its *Ornithodoros* tick ectoparasites, play a significant but closed bat-tick-bat cycle silently occurring in nature. (There may also be other species of bats involved, but we have no evidence of this. How the virus gets out of this cycle and enters the small-mammals-hard-tick-monkey-man cycle is yet to be studied. Some of the planet's scariest and most lethal viruses such as the Ebola and rabies find a natural refuge in bats. Bats and other animals such as rats and mice that chronically harbour viruses are important as disease reservoirs (*Frontline,* 1 March 2019). Pre-independence, India had done a lot of work on bats.

Rhinolophus rouxii was described as early as 1835 from Peninsular India. The literature shows:

"Rhinolophus rouxii Temminck*, 1835, Pondicherry and*

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*Calcutta, **India**. Rufous leaf bat. Fur soft and silky, color variable, from russet brown or Buffy brown. **Distribution:** Nepal, India, and Sri Lanka to southeastern China and Vietnam. **Habitat:** Forested regions in higher rainfall areas. **Behavior:** Roosts in caves, tunnels, hollow trees, wells, and buildings. Colonies vary from a few to several hundred individuals. Sexes live separately for at least part of the year (probably when young present), males living alone or in small groups, females in large colonies. Hibernates in colder parts of the range. **Feeding ecology and diet**: Begins feeding after sunset, catching insects on the wing for 30–60 minutes. Flight low, often through bushes. Then rests for 60–120 minutes before foraging throughout the night, "fly catching" from a perch. Eats primarily grasshoppers, moths, beetles, termites, mosquitoes, and other Diptera." These findings were made in British India, long more than a century ago.*

Barbara French writes,

"Forest inhabiting bat species which includes the Rufous horseshoe bat (*R. rouxii*), whose diurnal roosts tend to be humid and include caves, tunnels, hollow trees, wells, temples, old houses, and barns. The little-known little Nepalese horseshoe bat (*R. subbadius*) is recorded from bamboo clumps in dense jungle. Although Blyth's horseshoe bat (*R. Lepidus*) is normally associated with forested country, it is also recorded from a *desert biome* in India; its diurnal roosts include subterranean silos. The woolly horseshoe bat occurs in dense forests on precipitous mountains in the Kathmandu Valley, where it roosts in caves. The lesser woolly horseshoe bat is also restricted to the forest, where it roosts in hollow trees, small caves, and under ledges; it also uses dungeons, old houses, barracks, and tunnels. The trifoil horseshoe bat (*R. trifoliatus*) of southern, southeastern Asia and Malaysia lives in dense evergreen jungle and roosts in thick foliage. Lander's horseshoe bat (*R. landeri*) of Africa is predominantly a forest species but in the south of its range, it inhabits savanna woodland with riverine vegetation and well-watered areas. The presence of substantial shelters **(caves, mines, boulders, hollow trees)** is probably a critical habitat requirement."

The literature abounds studies on insectivorous bats in the last century.

There are no reports in the recent past of anyone deliberately looking for bats in all the areas/localities from where KFD cases have been reported. These bats are quite indigenous in some specialized habitats in Western Ghats. Nor are there any reports of entomologists, working on KFD, getting interested in *Ornithodoros* ticks parasitizing these bats. The study of maintenance of KFD virus in its natural habitats had received no attention from Indian scientists. Contrast this with considerable attention from Ugandan Virus Research Institute (UVRI). They have discovered dozens of diseases and pioneered a viral surveillance system that has played a critical role in curbing potential epidemics. The UVRI has shown that crisis management of the sort advocated by the World Health Organization (WHO) is a poor replacement for vigilant monitoring of potential public health crises in the first place and aggressively containing them once they arise**.** *"Ebola came; they react. When Zika came, there was a reaction,"* said Ernest Tambo, an epidemiologist who has worked throughout Africa. Uganda is a biodiversity hotspot," said Julius Lutwama, the UVRI's senior principal research officer. "We have wide flora, wide fauna, and, of course, the good temperature, the good climate. And what is good for humans, what is good for animals, of course, is also good for viruses." The presence in the country of so many of the world's most virulent pathogens has compelled it to become a **world leader in virus surveillance.** Martha Kaddumukasa, an entomologist at Uganda's Makerere University, said: "They're always monitoring the conditions, so that there's no outbreak that they're not aware of. An American Scientist, Dr Holly Lutz, has been working on bats and their roles in disease maintenance, in the Zika forest of **Uganda**, since 2016. This is where the headline-grabbing Zika virus was first discovered by the Uganda Virus Research Institute. She is trying to identify the natural reservoir of the Zika virus. "We want to continue sampling; we still have a lot of basic biodiversity exploration to do in Africa and other areas of the world" (Frontline, November 25, 2016).

Our scientists should: (1) first and foremost, undertake a comprehensive **literature review** on the current understanding and potential for bats to act as reservoirs for viruses transmitted by blood-feeding arthropods**; (**2**) sero-surveillance and viral isolation from either free-ranging or captive bats, in relation to four arbovirus groups** (Bunyavirales, Flaviviridae, Reoviridae, and Togaviridae) should be done; (3) **ecological associations between bats and haematophagous viral vectors (e.g., bat blood meals in mosquitoes, ingestion of mosquitoes by bats, etc).** should be studied, and (4) knowledge gaps related to haematophagous ectoparasites (bat bugs and bed bugs (Cimicidae) and bat flies (Nycteribiidae and Streblidae**))** must be filled , in addition to describing future directions for characterization of bat-vector-virus relationships (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6466281/).

Though bats are infamous, in fact, bats provide extraordinary benefits. Here are some benefits of having bats. Some bat species feed on night-flying insects including mosquitoes. As per some studies, they can eat as many as 1,200 insects in an hour of feeding! They act as pollinators and help in dispersal of seeds and fruits. Bats that feed on fruits play a very significant role in the dispersal of seeds. Thus, they can assist in reforestation, especially in regrowth of cleared and damaged rain forests. Bat excrement (guano) is a very effective organic fertilizer and its collection can have a very

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positive impact on local agriculture. Moreover, bats can be a tourist attraction! Thousands of bats live under a bridge in Austin, Texas. An estimated 10,000 people visit the bridge, to see the bats as they fly over the bridge each night. The revenue generated each year estimates to $10,000,000.

However, the problem caused by bats acting as disease vectors remains to be solved. Some suggestions are: A cadre of entomologist/field biologists should be created—especially for studying the zoonotic aspects of viral diseases. The apex research bodies should fund research on bats in universities and other voluntary organizations. There are no efficient zoonoses monitoring systems in place in our country. We need to form collaborative teams consisting of bat ecologists (there are several of them in many academic institutions), veterinarians, forest department officials, entomologists and health officials that would continuously monitor and sample biological material from bats living close to human habitations for virus/antibody presence. Such teams should engage with the local public and devise a strategy to prevent them from getting into close contact with the bats. But, one big complication is that these deadly viruses do not spread directly from bats; they rather use a secondary intermediate host that could be a variety of small to large mammals, for example, dogs for rabies, camels for MERS, and horses for lyssa and hanta viruses and so on. So our efforts should encompass a variety of animals and not just the bats. There may be many individuals, or organizations like, for example, The Centre for Behavioral and Immune Ecology within the St. John's College in Palayamkottai, Tamil Nadu which has been working on bats, without much recognition from the apex research bodies for the last two decades! They must be encouraged and supported with more facilities and personnel. Long ago, in 1954s, The Rockefeller Foundation established Virus diagnostic laboratories in select medical colleges all over India to serve as local testing centres. These were closed in 1970, for reasons unknown. One cannot depend on sending samples for testing all the way to Delhi (NCDC) or Pune (NIV) every time an outbreak occurs. There is sufficient funding available with our government to **establish centres for zoonotic study and undertake zoonotic niche mapping.** Without an objective to establish more regional centres for research, survey and diagnostic facilities, we should be prepared, in the future, not only for epidemics of Ebola and KFD, but also for the dangerous scourge, **Yellow Fever**!

Image of *Miniopterus inflatus*-Ebola Virus

Image of Rufous Horseshoe Bat, *Rhinolophus rouxii*, reservoir for KFD Virus

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