Journal of Chemical Health Risks

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JCHR (2025) 15(5), 3242-3249 | ISSN:2251-6727

Field based Epidemiological Survey of Kyasanur Forest Disease Cases During the 2018–2020 Outbreak

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(Received: 27 September 2025 Revised: 05 October 2025 Accepted: 14 October 2025)

KEYWORDS

Kyasanur Forest Disease, Kyasanur Forest Disease Virus, Vaccine

ABSTRACT:

Kyasanur Forest Disease (KFD) is a tick-borne viral hemorrhagic fever endemic to the Western Ghats of India. In recent years, the disease has shown an expanding geographic distribution, raising public health concerns. A field-based epidemiological survey was conducted during the 2018-19 and 2019-20 KFD outbreaks across the districts of Shivamogga, Chikkamagaluru, and Uttara Kannada in Karnataka. Data on confirmed cases, vaccination status, mortality, and behavioral risk factors were collected and analyzed. The 2018-19 outbreak in Aralagodu village, Sagar Taluk, resulted in 20 deaths and established the area as a new KFD hotspot. During 2019-20, newer regions such as N. R. Pura and Siddapura Taluks reported 60 confirmed cases. Despite ongoing vaccination programs (prior to their suspension in 2020), several breakthrough infections occurred among individuals who had received two or more doses, indicating limited vaccine-induced immunity. However, vaccinated individuals generally experienced milder disease, while unvaccinated patients presented with severe hemorrhagic and neurological symptoms. Behavioral exposure, particularly forest visits for collecting leaf litter and firewood, emerged as a key risk factor. Additionally, displacement of infected bonnet macaque troops was observed, suggesting a possible ecological driver of viral spread. The findings highlight the persistent challenges in KFD control, emphasizing the need for a more effective vaccine, strengthened public awareness initiatives, and integrated ecological surveillance to mitigate future outbreaks and limit the disease's spread to new regions.

1. Introduction:

Kyasanur Forest Disease (KFD) is an acute, tick-borne viral hemorrhagic fever that poses a significant public health threat in southern India. The disease is caused by the *Kyasanur Forest Disease Virus* (KFDV), a member of the genus *Flavivirus* within the family *Flaviviridae*. Transmission to humans occurs primarily through the bite of infected hard ticks, *Haemaphysalis spinigera* (Holbrook, 2012). The KFDV genome consists of a positive-sense, single-stranded RNA of approximately 11 kb, encoding three structural proteins, capsid (C), precursor membrane (prM), and envelope (E) as well as seven non-structural proteins (NS1, NS2A, NS2B, NS3, NS4A, NS4B, and NS5), which play essential roles in viral replication, host immune evasion, and pathogenesis (Shah et al., 2018).

Despite more than six decades of research since its discovery, no specific therapy exists for KFD. Disease control efforts have primarily relied on preventive measures, such as vaccination and tick management. The formalin-inactivated KFD vaccine, which was used until 2022, has demonstrated limited efficacy, as evidenced by the occurrence of breakthrough infections among vaccinated individuals (Kasabi et al., 2013). Laboratory confirmatory diagnosis of KFD cases generally relies on molecular assays such as reverse transcription polymerase chain reaction (RT-PCR) and serological methods detecting KFDV specific IgM antibodies using enzyme-linked immunosorbent assay (ELISA) (Mourya et al., 2012).

KFD exhibits a distinct seasonal pattern, with outbreaks occurring mainly between November and June, coinciding with increased tick activity in forested regions. Humans and non-human primates particularly bonnet macaques (*Macaca radiata*) and langurs (*Semnopithecus entellus*) serve as the principal susceptible hosts, while small mammals such as rodents and shrews act as maintenance hosts, supporting the

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JCHR (2025) 15(5), 3242-3249 | ISSN:2251-6727

persistence of the tick-virus cycle in the environment (Pattnaik, 2006). The disease was first recognized in 1957 in the Kyasanur Forest area of Soraba Taluk, Shivamogga District, Karnataka, India. Since then, its geographic distribution has progressively expanded beyond Karnataka to include the neighboring states of Maharashtra, Gujarat, Kerala, and Tamil Nadu (Awate et al., 2016; Patil et al., 2017; Sadanandane et al., 2017; Gaurav et al., 2018; Yadav et al., 2018). This expansion reflects complex interactions between ecological, environmental, and anthropogenic factors, including forest fragmentation, human encroachment, and movement of infected animal hosts. The reported case-fatality rate for KFD varies between 2% and 10%, largely depending on the timeliness of diagnosis and the quality of clinical care provided (Vedachalam et al., 2024).

Given its expanding range and recurring seasonal outbreaks, KFD continues to be a major public health concern in the Western Ghats region. Continuous epidemiological surveillance is critical to understand the transmission dynamics of the virus, identifying new endemic hotspots, and evaluating the effectiveness of existing control measures. Furthermore, field-based studies provide essential data on vaccine performance under real-world conditions and on the behavioral and ecological risk factors associated with infection. In this context, the present study aimed to conduct a field-based epidemiological assessment of KFD outbreaks during 2018-20 across the Shivamogga, Chikkamagaluru, and Uttara Kannada districts of Karnataka. The study focused on characterizing clinical severity among affected individuals, evaluating vaccine effectiveness and ecological risk factors contributing to disease transmission in newly affected regions.

2. Methods:

2.1 Study Design

A retrospective analysis of Kyasanur Forest Disease (KFD) surveillance data was conducted for the three-year period from 2018 to 2020, focusing on two major outbreak seasons: 2018-19 and 2019-20. The primary objective was to identify patterns in disease transmission, demographic characteristics of affected individuals, clinical manifestations, and vaccination coverage in the endemic districts of Karnataka, India.

2.2 Data Collection Approach During the 2018-19 Outbreak

During the 2018-19 outbreak, preliminary data were obtained through secondary sources, including systematic screening of local newspapers and media reports to identify villages reporting KFD cases or deaths. This media-based surveillance enabled the rapid identification of potential outbreak hotspots for subsequent field investigations. A field visit was subsequently conducted to Aralagodu village, located in Sagar Taluk of Shivamogga District, Karnataka-one of the most severely affected areas during that season. The visit was undertaken in collaboration with the District Commissioner's Office and local health authorities to assess the on-ground situation and to collect detailed epidemiological information on reported cases. Data were gathered through interviews with community members, affected individuals, and healthcare workers, focusing on reported symptoms, suspected risk factors, and perceptions of disease transmission and vaccine uptake. This qualitative approach provided valuable contextual insights into community-level awareness, prevention practices, and challenges in outbreak response.

2.3 Field-Based Surveillance During the 2019-20 Outbreak

During the 2019-20 KFD outbreak, a more structured and proactive data collection strategy was implemented. The investigation commenced with visits to Primary Health Centers (PHCs) serving the affected villages to review clinical records and obtain line lists of laboratory-confirmed KFD cases. These data facilitated preliminary case mapping and identification of high-incidence areas for targeted field assessment. Subsequently, community-level surveys were conducted among individuals who had tested positive for KFD by reverse transcription polymerase chain reaction (RT-PCR) or enzyme-linked immunosorbent assay (ELISA). These in-person interviews were designed to collect comprehensive information on Demographic characteristics (age, sex, and occupation), Clinical presentation (symptom onset, duration, and severity), Vaccination history (number of doses received and timing relative to exposure), Exposure risk factors (occupational exposure, forest visits, and reported tick bites), Health-seeking behavior (timing of first

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healthcare contact and type of medical facility visited) and Clinical outcomes (recovery status, complications, or mortality).

This mixed-methods approach, integrating passive surveillance data from PHCs with active community-based surveys, enabled triangulation of information from multiple sources. This comprehensive strategy enhanced the reliability, completeness, and contextual depth of the epidemiological dataset, allowing for a more accurate characterization of KFD transmission dynamics during the study period.

3. Results:

3.1 Field study report of KFD outbreaks: 2018-19 and 2019-20

3.1.1 KFD Outbreak: 2018-19

In response to the Kyasanur Forest Disease (KFD) outbreak during the 2018-19 transmission season, official permission was obtained to conduct a field investigation in collaboration with the District Commissioner of Shivamogga and the District Health Department. A detailed epidemiological field survey was undertaken in Aralagodu village, located in Sagar Taluk, Shivamogga District, which had reported a sudden and significant rise in suspected KFD cases. Aralagodu village, which had not previously been identified as a KFD hotspot, emerged as the epicenter of the outbreak, reporting 20 human fatalities associated with confirmed KFD infections (Table 1). This represented one of the most severe local outbreaks documented during that season. The adjacent Thirthahalli Taluk also reported a smaller cluster of confirmed cases, indicating possible regional spread and overlapping transmission zones within the district. The 2018-19 outbreak in Aralagodu thus marked a critical turning point in KFD epidemiology in the region, highlighting the emergence of new transmission foci beyond historically recognized endemic zones.

3.1.2 KFD outbreak: 2019–2020

During the 2019-20 KFD outbreak**,** the study area was expanded to include both previously affected zones and newly emerging foci across the Shivamogga, Chikkamagaluru, and Uttara Kannada districts of Karnataka (Figure 1). Field investigations and data collection were conducted in close collaboration with Taluk Health Officers (THOs) and Health Inspectors from Primary Health Centres (PHCs) operating in the affected regions.

A. Thirthahalli and Sagara taluk (Shivamogga District)

Field investigations were carried out in the villages of Konanduru Division (Dyamalapura, Kankalli, Hullatti, and Baavikysaru) and Mandagadde Division (Sindhubavi), followed by surveys in Sagara Taluk (Aralagodu, Arishinagodu, Balegaru, and Kanuru). According to PHC records, a total of 46 laboratory-confirmed KFD cases were reported from Thirthahalli Taluk, and 15 confirmed cases were reported from Sagara Taluk during this period. The majority of affected individuals were adults engaged in occupations involving direct or indirect forest exposure, such as leaf-litter collection and firewood gathering. The data presented here are current up to 16 March 2020, when field activities were suspended due to the nationwide COVID-19 lockdown. Notably, two children under five years of age were also diagnosed with KFD. Both cases occurred among unvaccinated children, consistent with national vaccination guidelines that exclude this age group due to the absence of safety data (MoHFW, 2020). In addition, two langur (monkey) deaths suspected to be associated with KFD were reported in Kanuru village, suggesting active viral circulation in local non-human primate populations. As part of vector control measures, malathion powder was applied within a 5–10 m radius around the sites of confirmed monkey deaths, in accordance with government-recommended tick control protocols.

B. N. R. Pura Taluk (Chikkamagaluru District)

This outbreak represented the first recorded occurrence of KFD in Madaburu village, located in N. R. Pura Taluk, underscoring the progressive geographic expansion of the disease into new areas of the Western Ghats. A total of seven laboratory-confirmed cases were reported during the 2019-20 season, with the majority of affected individuals being coffee estate workers who had frequent exposure to tick-infested forested environments. Epidemiological investigation revealed that several of the affected individuals had a recent travel history to Mandagadde (Thirthahalli Taluk), a region previously recognized as an active KFD transmission zone suggesting possible human-mediated introduction or cross-regional viral transmission.

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C. Siddapura Taluk (Uttara Kannada District)

During the 2019-20 transmission season, Siddapura Taluk in Uttara Kannada District reported multiple laboratory-confirmed cases of KFD, marking the continued westward spread of the disease. Surveillance data from Kyadagi Primary Health Centre (PHC) documented seven confirmed cases, while Kanasuru PHC reported three confirmed cases. In addition, one KFD-associated fatality was recorded during this period. Field investigations were conducted through household visits to all affected families, during which information was collected on clinical manifestations, exposure history, and vaccination status of each case. These observations contributed valuable field-level evidence on disease presentation and community-level risk factors associated with KFD transmission in this newly affected area.

3.1.4 Monkey behavior and disease spread

During field observations in the coffee estates surrounding Madaburu village, a notable ecological behavior was recorded among bonnet macaque (*Macaca radiata*) troops. When a death occurred within a troop, the surviving members were observed to abandon the area and migrate to adjacent forest patches or coffee plantations. This dispersal behavior likely contributes to the movement of infected ticks (*Haemaphysalis spinigera*) across new ecological zones. Such macaque-mediated tick dispersion may play a critical role in the geographical expansion of KFD into previously unaffected regions along the Western Ghats, highlighting the importance of KFD surveillance and control strategies.

3.2 Vaccine effectiveness

3.2.1 Community perception and vaccine hesitancy

Field observations and interviews conducted in the affected villages revealed growing vaccine hesitancy among community members, many of whom expressed reluctance to participate in the ongoing KFD vaccination program. The primary reasons cited for this resistance included reports of breakthrough infections among vaccinated individuals leading to a perception that the vaccine was ineffective as well as local adverse reactions such as pain, redness, and irritation at the injection site. Despite the continuation of the KFD vaccination campaign within a 5 km radius around outbreak epicenters, several new cases were documented among previously vaccinated individuals. According to patient interviews, most had received one or two doses of the vaccine, while a few had completed the recommended three-dose schedule within months preceding the outbreak. These findings suggest the possibility of a suboptimal immunogenic response or reduced vaccine effectiveness under field conditions, consistent with earlier reports from other endemic regions. Notably, reinfections were also reported in individuals who had both a prior history of KFD infection and subsequent vaccination, indicating potential waning immunity or incomplete protection conferred by either natural infection or vaccination. Together, these observations underscore the need for further immunological and field-based studies to reassess vaccine performance and durability of protection in endemic populations.

3.2.2 Clinical outcomes in vaccinated vs. unvaccinated individuals

Despite concerns regarding vaccine efficacy, field observations indicated that disease severity was notably lower among vaccinated individuals. In most vaccinated cases, clinical manifestations were limited to a self-limiting febrile illness, and patients typically recovered without major complications. In contrast, unvaccinated individuals, particularly those with no prior exposure or immunity, frequently developed severe forms of KFD. These cases presented with hemorrhagic manifestations such as bleeding gums, epistaxis, and gastrointestinal bleeding, along with neurological complications in some instances, including altered sensorium, tremors, and encephalitis-like presentations. These findings suggest that vaccination, while not fully protective against infection, may attenuate disease severity.

3.2.3 Behavioral risk and environmental transmission

A recurring behavioral pattern observed among many KFD-affected individuals was frequent visits to forested areas for the collection of dry leaf litter used as organic manure and for gathering firewood. These activities typically involve prolonged exposure to tick-infested habitats, particularly the leaf litter layer on the forest floor, where nymphal Haemaphysalis ticks, the primary vectors of KFDV, are most active. Following collection, these organic materials are often transported and stored

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near residential premises, creating opportunities for tick dispersion into human dwellings. This proximity increases the risk of secondary infections among household members, including children and elderly individuals, who may have limited direct forest exposure (Figure 1).

4. Discussion:

The dual-season investigation strategy provided valuable insights into both the epidemiological characteristics of KFD outbreaks and the operational dimensions of surveillance, vaccination coverage, and public health response. In addition to documenting outbreak patterns, the field surveys highlighted key community-level challenges, including underreporting of cases, delayed healthcare seeking, vaccine hesitancy, and knowledge gaps regarding tick exposure and disease prevention. These findings underscore the importance of integrating community engagement and health education into future public health interventions and outbreak preparedness programs in endemic regions.

Following the outbreaks, Sagar Taluk was identified as a newly emerging KFD hotspot. Within this taluk, Aralagodu village recorded the highest mortality, and disease spread was subsequently documented in the neighboring Manduvalli village, where two additional deaths occurred. Both deceased individuals were middle-aged adults (≥35 years), consistent with earlier observations that adults engaged in outdoor occupations are at greater risk of KFD infection (Patil et al., 2017; MoHFW, 2020). Across all affected sites, a consistent behavioral risk factor reported was the collection of dry forest litter (leaves) for use as organic manure. This activity, commonly performed by rural populations during the dry season, requires frequent and prolonged entry into forested areas, thereby increasing exposure to tick-infested habitats. The timing of this activity coincides with the peak nymphal activity of Haemaphysalis ticks, further amplifying the risk of human infection (Geevarghese and Mishra, 2011).

Deforestation and agricultural expansion in the Western Ghats have significantly altered the ecological balance of the region, influencing both vector distribution and host dynamics. The conversion of forest land into coffee estates and farmlands attracts monkey populations, as these areas lie along the forest periphery and provide an ideal habitat for tick proliferation and wildlife reservoirs (Murhekar et al., 2019). Coffee plantations are often rich in fruit-bearing trees, which attract red-faced bonnet macaques (*Macaca radiata*), thereby increasing the frequency of human–wildlife interactions and heightening the risk of zoonotic transmission of KFDV.

Despite successful vaccination campaigns, a considerable number of laboratory-confirmed KFD cases occurred among vaccinated individuals during both the 2018-19 and 2019-20 outbreak seasons. Many of these individuals had received two or even three doses of the formalin-inactivated KFD vaccine prior to the onset of illness. These findings raise concerns regarding vaccine immunogenicity and its ability to elicit durable immune memory under real-world field conditions (Kasabi et al., 2013; Kiran et al., 2015; Mourya et al., 2014).

Although the current KFD vaccine appears to offer partial protection and attenuates disease severity, several limitations hinder its overall effectiveness. These include short-lived immunity, adverse local reactions, and public mistrust toward the vaccination program. Reported side effects are commonly linked to residual formalin used during viral inactivation resulting in pain, redness, and swelling at the injection site. As the vaccine is administered subcutaneously, these reactions have discouraged many recipients from completing the recommended two-dose primary schedule and booster regimen, which are essential for optimal protection (Mourya et al., 2019; MoHFW, 2020).

These observations are consistent with earlier reports suggesting that while the vaccine may not prevent infection, it can significantly reduce disease severity and fatality rates among those who develop the illness (Kasabi et al., 2013). To enhance vaccine performance and acceptance, reformulation of the existing vaccine, inclusion of broader age groups, and community-based awareness initiatives are urgently needed to improve overall vaccine uptake and herd immunity in endemic areas. A particularly concerning finding was that vulnerable populations, including children under five years of age and elderly individuals above 65 years, remain unvaccinated due to the lack of safety and efficacy data for these age groups (MoHFW, 2020). These groups are therefore at elevated risk, especially in

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highly endemic areas where seasonal transmission is well established and exposure to infected ticks is recurrent.

Conclusion:

In conclusion, findings from our field surveys conducted across two outbreak seasons highlight several key trends: (1) the expanding geographical spread of KFD into previously unaffected areas, (2) the occurrence of breakthrough infections among vaccinated individuals, (3) the emergence of reinfections and pediatric cases beyond the current vaccine coverage group and (4) the potential influence of monkey troop behavior and human–forest interactions on disease transmission. These observations emphasize the urgent need to re-evaluate existing vaccination strategies, strengthen community awareness programs and enhance ecological surveillance to more effectively predict and prevent future KFD outbreaks in the Western Ghats region.

In conclusion, findings from our field investigations conducted over two consecutive outbreak seasons (2018-19 and 2019-20) reveal several critical epidemiological and ecological trends. These include: (1) the progressive geographic expansion of KFD into previously unaffected regions of the Western Ghats; (2) the occurrence of breakthrough infections among vaccinated individuals; (3) the emergence of reinfections and pediatric cases outside the current vaccine coverage group; and (4) the potential influence of monkey troop dispersal behavior and human–forest interactions on the spread of infection. Collectively, these findings underscore the need to reassess existing vaccination strategies, including dose schedules and target populations, and to strengthen community-based awareness and education programs in endemic areas. Furthermore, integrating ecological and behavioral surveillance with traditional epidemiological monitoring could enhance early detection and prediction of outbreaks in the Western Ghats region.

Conflict of Interest:

The authors declare no conflict of interest

Author's Declaration

Authors declare that the work presented in this manuscript is original and has not been published or submitted elsewhere, either in whole or in part. All authors have made significant contributions to the conception, design, data collection, analysis and interpretation of the study. All authors have reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Funding Declaration

Authors are thankful to VGST, Govt of Karnataka, for the financial support provided to conduct the study.

Ethical declaration

This study was conducted as part of public health field investigations on KFD under the project implemented by Government of Karnataka (VGST). Necessary administrative permissions for field surveys and data collection were obtained from the respective district authorities. Informed consent was obtained from all participants prior to interviews and all data were anonymized to ensure confidentiality and privacy.

Acknowledgements

The authors gratefully acknowledge the support of the Vision Group on Science and Technology (VGST), Government of Karnataka, for funding this work under the K-FIST (Level-2) program. We extend our sincere thanks to the District Health Officers, field health staff and local administrative authorities of the affected regions for their cooperation during data collection and field investigations. The authors also thank the community members and participants for their valuable time and willingness to share information during the surveys.

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JCHR (2025) 15(5), 3242-3249 | ISSN:2251-6727

Figures and Tables:

Table 1: List of deaths due to KFD during the 2018-19 outbreak.

Age groups (Year)	No. of deaths	Sex	
		Male	Female
01-20	01	-	01
20-40	03	02	01
40-60	10	06	04
60-80	06	02	04
Above 80	-	-	-
Total		20	

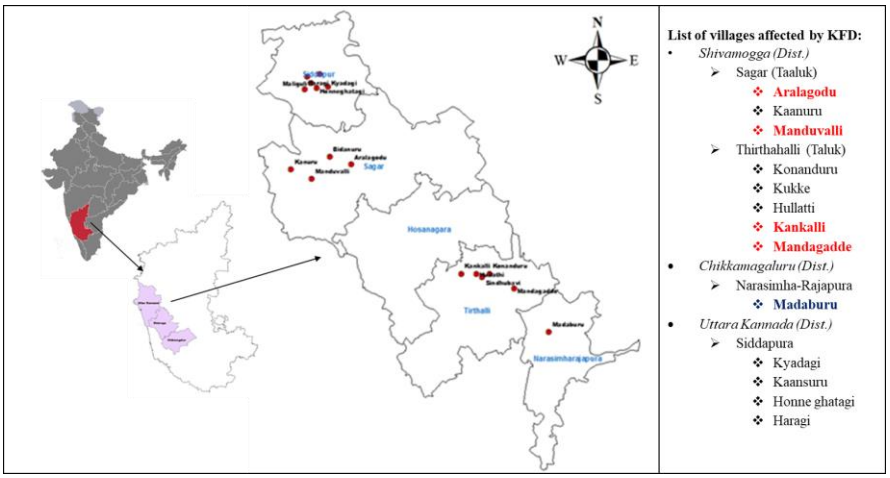

Figure 1: Map showing regions affected by KFD during the 2018-20 outbreak. *Regions marked in red indicate areas highly affected during the outbreak, while the region colored in blue represents the new zone of KFD expansion.*

Figure 2: Litter collected near residential area, serving as a potential reservoir for ticks.