Rift Valley fever in Tunisia: Review of the current situation and perspectives

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Keywords

Rift Valley fever virus, epidemiology, risk factors, Tunisia

Submitted: 18 August 2022
Accepted: 14 March 2023
Published: 13 April 2023
DOI: 10.19182/remvt.36975

Summary

Rift Valley fever (RVF) is an emerging zoonotic disease that infects humans and ruminants. It is caused by the RVF virus, an arbovirus mainly transmitted by *Aedes* and *Culex* mosquitoes' bites. In the last two decades, RVF cases have been reported in regions that were previously free of the disease, and epidemics have occurred more frequently. Tunisia has a strategic geographical location in the Mediterranean Basin and has important exchanges with other African countries as well as with Europe. The analysis of RVF epidemiological situation in this country could help to understand the global RVF epidemiology in the Mediterranean area and to design efficient surveillance strategies to be implemented in the region. In this context and to study the current status of RVF in Tunisia, this review analyzes all the published scientific papers related to the disease in the country. Tunisia is considered at high risk of RVF spread due to its geographic location, climatic and environmental characteristics, abundance of RVFV-virus vector species, and presence of susceptible animal species. Thus, strict measures must be taken to control and limit any RVF emergence and spread. Such measures must include control of animal movements (especially at borders), vector species control, and improving diagnosis tools for early detection of any suspected cases. The implementation of a multidisciplinary 'One Health' approach would be one of the best solutions to control vector-borne zoonotic diseases such as RVF.

■ How to quote this article: Mejri S., 2023. Rift Valley fever in Tunisia: Review of the current situation and perspectives. *Rev. Elev. Med. Vet. Pays Trop.*, 76: 36975, doi: 10.19182/remvt.36975

■ INTRODUCTION

Rift Valley fever (RVF) is an acute arboviral disease in humans, livestock and some wildlife species such as African buffaloes (Nielsen et al., 2020b). It is caused by the Rift Valley fever virus (RVFV; genus: *Phlebovirus*, family: *Phenuiviridae*, order: *Bunyavirales*), an enveloped virus with a single-stranded RNA genome (Gerrard and Nichol, 2007; Pepin et al., 2010). RVF seriously impacts the health of domestic ruminants and leads to important economic losses. Human disease ranges from mild febrile illness to severe disease and death (Sow et al., 2014; Mohamed et al., 2010). The disease was first described in 1930 in the Great Rift Valley of Kenya (Daubney et al., 1931) and was reported only in African countries until 2000, after which time a massive outbreak was declared in the Arabian Peninsula (Nanyingi et al., 2015). Virus transmission occurs mainly from the bites of infected mosquitoes, mostly those of *Aedes* and *Culex* genera (Dietrich et al., 2017). The risk of RVFV spread into new areas is of paramount importance, and countries such as Tunisia are considered at high risk for RVF incursions and epizootic occurrence (Arsevska et al., 2016). The aim of the present literature review was to analyze RVF situation in Tunisia. All the published studies related to RVF in this country were analyzed to evaluate RVF seroprevalence and assess risk factors involved in disease spread. We tried to predict epidemiological changes that may occur in the future, and to suggest adapted surveillance measures to be implemented.

■ EPIDEMIOLOGY

Rift Valley fever virus hosts

RVFV infection has been described in many mammalian species including wild animals such as lions, bats and African buffaloes (Boiro et al., 1987; Hartman, 2017; Nielsen et al., 2020b). The most susceptible animals are domesticated ruminants: cattle, sheep and goats. The susceptibility to infection and the mortality rate in infected animals depend on species and age. In fact, sheep are the

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most susceptible species, and higher mortality rates are observed in developing fetuses and newborn animals (Ikegami, 2012; Fawzi and Helmy, 2019; Hartman, 2017). RVFV is transmitted by mosquitoes. During epizootics, transmission from animal to animal and/or from animals to humans could occur by direct contact with animal products (e.g. aborted fetuses, blood) during handling of infected animals or carcasses (Cêtre-Sossah and Albina, 2009). People can also be infected by infected-mosquito bites, but few studies have investigated this transmission path (Anyangu et al., 2010; Tantely et al., 2015). Fortunately, no human-to-human transmission has been recorded to date, thus humans are considered as dead-end hosts in the epidemiological cycle of RVF (Nielsen et al., 2020b).

Rift Valley fever virus vectors

RVFV has been isolated from samples of more than 50 species of mosquitoes belonging to eight genera of the *Culicidae* family (Linthicum et al., 2016). Among these genera, six were confirmed to transmit RVFV experimentally in the laboratory: *Aedes*, *Anopheles*, *Coquillettidia*, *Culex*, *Eretmapodites* and *Psorophora* (Lumley et al., 2017). Species of *Aedes* and *Culex* genera are considered the main vectors involved in RVFV transmission (Nielsen et al., 2020b; Lumley et al., 2017). RVFV vectors are classified into primary or maintenance vectors (mainly *Aedes* species), and secondary or amplifying vectors (mainly *Culex* species). The role of primary vectors is to maintain virus viability in eggs of the vectors during the dry season. The secondary vectors are involved in the transmission of RVFV after its replication in host animals (Fawzi and Helmy, 2019; Lumley et al., 2017; Mohamed et al., 2013; Kwaśnik et al., 2021).

Geographic distribution of Rift Valley fever

RVF had been limited to some African areas until it emerged outside of Africa in 2000 in the Arabian Peninsula. Other outbreaks have been declared in other regions such as in the islands of Madagascar in 1990-1991 (Morvan et al., 1991) and in 2008-2009 (Andriamandimby et al., 2010), and of Mayotte (French overseas department) in 2018 (Youssouf et al., 2020). In endemic regions, the re-emergence of RVF outbreaks has often been associated with heavy rainfall periods (Sow et al., 2014; Fawzi and Helmy, 2019).

As with many other arboviruses, some changes have been observed in the epidemiology of RVFV; Evidence of disease introduction into new regions such as Iran, Turkey, Algeria and Tunisia, has been reported (Fakour et al., 2017; Gur et al., 2017; Nardo et al., 2014; Bosworth et al., 2016; Selmi et al., 2020; Hellal et al., 2021). Also, the occurrence of RVF epidemics has been more frequently reported (Nielsen et al., 2020b).

Risk factors

RVF emergence in new regions has been mostly associated with the importation of infected ruminants. This was assumed after the introduction of RVF in the Arabian Peninsula (Shoemaker et al., 2002), Egypt (Fawzi and Helmy, 2019) and Madagascar (Carroll et al., 2011). RVF spread and re-emergence result from the combination of many factors, in particular the expansion of distribution of competent vectors due to heavy rainfall, the presence of stagnant water points and/or lakes or rivers, dam construction at water points, the movement and trade of live animals, and the density of ruminants (Nielsen et al., 2020b; Mohamed et al., 2013; Metras et al., 2011; Javelle et al., 2020). The risk of human infection is significantly higher in some occupational groups such as veterinarians, butchers, farmers and slaughterhouse workers (Fawzi and Helmy, 2019; Bosworth et al., 2016). The increase of detected RVF positive cases could partly be linked to the improved sensitivity of currently used diagnostic tests.

Rift Valley fever in animals

In sheep and goat herds, RVF disease is mainly recognized by widespread abortion waves. Infected pregnant females abort at any gestation period, with a rate reaching 100% (Pepin et al., 2010). The case fatality risk varies depending on the species and age of the animal, and ranges from 70% to 100% in infected young animals (Gerdes, 2002). Adult animals show different clinical forms, from asymptomatic to severe acute disease leading to death (Kwaśnik et al., 2021). Due to virus tropism to hepatocytes, most observed lesions in infected animals occur in the liver and include necrosis and hemorrhages (Hartman, 2017). Cattle are less susceptible to RVF than sheep and goats, and infected adult animals are often asymptomatic (Kwaśnik et al., 2021). However, few cases of acute disease and mortality have been described in cattle (Kwaśnik et al., 2021).

Camels are susceptible to infection by RVFV, and abortion waves associated with the disease have been described. In most cases of infected adult camels, no clinical signs were observed. However, some per-acute cases or acute forms leading to death have been reported (El Mamy et al., 2011). It is likely that this animal species acts as an amplifying host and virus carrier (Nielsen et al., 2020b).

Rift Valley fever in humans

Most RVF human cases are subclinical (Nielsen et al., 2020b). The disease varies from a self-resolving influenza-like illness (described in most of the symptomatic cases) to severe forms including hemorrhagic fever, hepatitis, retinitis, renal failure and encephalitis. Such severe forms can be fatal (Pepin et al., 2010; Hassan et al., 2017). There are no specific treatments for RVF, and unfortunately no human vaccine against RVFV is commercially available yet (Hartman, 2017; Nielsen et al., 2020b).

■ MEDITERRANEAN REGION

Among Mediterranean countries, only Egypt has experienced several RVF epidemics in 1977, 1993, 1997 and 2003 (Helmy et al., 2017). The expansion of RVF has increased over the last decades, and seropositive cases have been recently reported from officially RVF-free Mediterranean countries. In Algeria (in the Sahrawi refugee camps) seropositive animals have been reported (Di Nardo et al., 2014). In Tunisia and in Turkey, seropositive cases were observed in ruminants and in humans (Bosworth et al., 2016; Hellal et al., 2021; Selmi et al., 2020; Gur et al., 2017). More recently, in the early 2020s the Libyan veterinary authorities notified the World Organisation for Animal Health of an RVF outbreak that started in December 2019 in the south-east of the country. Samples from sheep and goats were detected immunoglobulin G (IgG) positive, however, data about the origin of these seropositive animals were lacking (OIE, 2020). Information about animals' origin was important since during the same period an epidemic was reported in Sudan (Nielsen et al., 2020b). Human cases described in Tunisia (Bosworth et al., 2016), a Mediterranean country considered RVF free, could confirm a possible silent circulation of RVFV; Unfortunately, in that study, results have been hampered because samplings were not carried out according to epidemiological criteria, and the investigated areas and/or sample size were limited. IgG and IgM were detected with the indirect immunofluorescence technique (kits from Euroimmun, Lübeck, Germany) which is characterized by limited specificity (Nielsen et al., 2020b). Moreover, all reported serological results have not been confirmed by the virus-neutralization technique (VNT), i.e. the most specific serological technique in RVF diagnosis (OIE, 2018). In Egypt, an RVF endemic country, human cases were reported during major outbreaks in 1977, 1978, 1994, 1997 and 2003 (Fawzi and Helmy, 2019).

The Mediterranean Basin comprises more than 20 countries, most of them are European. Although the overall risk of RVF introduction in Europe is very low, the movements of infected animals and vectors are considered as plausible pathways for RVF introduction in Europe (Nielsen et al., 2020b; Kwaśnik et al., 2021). Considering the presence of high numbers of susceptible species and competent vectors in Europe associated with climatic changes, it is of paramount importance for European countries to strengthen surveillance and control measures, and to collaborate with countries of North Africa and the Middle East to prevent RVF entry (Kwaśniket al., 2021; Sánchez-Vizcaíno et al., 2013). RVF human cases have been described in European travelers after their return from endemic areas to Europe (Tong et al., 2019). This raises the questions whether such human cases are still infectious and play a role in the spread of the virus, especially if the viral load is high. Even if no human-to-human RVF transmission has been observed, further studies are needed to explore human infectiousness and how humans can transmit the virus. The sustained transmission and establishment of RVFV in European countries are unlikely (Rolin et al., 2013). However, global climate change may influence and enhance the probability of virus establishment in Europe.

■ RIFT VALLEY FEVER IN TUNISIA

A review of the literature on the RVF situation in Tunisia and the factors involved in the introduction and spread of the virus in the country was performed without exclusion criteria. We searched all papers in PubMed electronic database from an unlimited period until June 2022. Search terms used to identify articles were: ([‘Rift Valley Fever’ or ‘RVF’] and ‘Tunisia’), ([‘Rift Valley Fever’ or ‘RVF’] and ‘North Africa’), ([‘Rift Valley Fever’ or ‘RVF’] and ‘Tunisia’ and ‘risk factors’), ([‘Rift Valley Fever’ or ‘RVF’] and ‘Tunisia’ and ‘surveillance’). About 220 articles fulfilled the inclusion criteria. Some relevant references cited in the eligible papers were also included for specific purposes of the present review.

Past and current situation

The first study reporting results of RVFV serological screening in Tunisia was published by Ayari-Fakhfakh et al. in 2011 and showed no serological evidence of RVF. The study had been conducted on 610 samples from sheep, goats, cattle and camels from different geographic areas of the country between 2006 and 2007 using an inhibition ELISA technique.

Since 2015, the number of published works on RVF in Tunisia has increased, and sporadic seropositive cases have been reported. In 2016, Bosworth et al. reported 18 human seropositive cases out of 219 investigated people (181 febrile patients, and 38 non-febrile healthy agricultural and slaughterhouse workers). They detected reactivity of IgG in three sera from non-febrile healthy workers, and of IgM in 15 sera from febrile patients. More recently, in 2021 Zouaghi et al. reported serological evidence of RVFV circulation in animals; IgG positivity was detected in sera from sheep and cattle from north Tunisian regions. In these two studies, samples were tested using the commercial ID Screen Rift Valley fever competition multispecies ELISA (ID. vet Innovative Diagnostics, Montpellier, France) and/or the commercial indirect immunofluorescence assay RVFV IIFA (Euroimmun). Detected seropositive cases were not confirmed by VNT.

Another recent study was performed on a sampling based on specific selection criteria that involved a serological cross-sectional survey in Tunisian regions considered at high and very high risk of RVF introduction (Kalthoum et al., 2021); a total of 1287 sera from 1114 small ruminants and 173 camels were tested with the ELISA ID.vet kit previously mentioned, and VNT was used to confirm ELISA positive results. Results showed that only one sample, collected from a ewe from Northeastern Tunisia, was detected IgG positive by ELISA but not confirmed by VNT.

The only study reporting positive ELISA results confirmed by the VNT technique is that of Hellal et al. (2021). It was carried out on the largest sample ever in Tunisia for RVF screening. Indeed, 1723 serum samples from sheep, goats, cattle and dromedaries from different Tunisian regions were investigated; three samples (one sheep, two cattle) from central regions were detected IgG positive by ELISA and confirmed by VNT.

Regarding RVF in Tunisian camels, three studies have been published. Kalthoum et al. (2021), and Ben Hassine et al. (2017) investigated 118 and 173 serum samples, respectively, each using the commercial ID Screen Rift Valley fever competition multi-species ELISA kit. Results of both works confirmed there were no RVF seropositive cases in the camels. Selmi et al. (2020) published the only work that reported RVF seropositive cases in a sample of 470 dromedaries from six regions in Southern and Central Tunisia. Samples were tested using the same ELISA kit mentioned in the two studies above. Results showed that 34% (162/470) of investigated sera were detected seropositive (IgG reactivity), however, positive ELISA results were not confirmed by any other technique.

According to the literature, RVF cases have been described in Tunisia since 2014 (Bosworth et al., 2016) and since that year more and more positive cases have been reported (Selmi et al., 2020; Hellal et al., 2021; Kalthoum et al., 2021; Zouaghi et al., 2021) (Figure 1). The relatively recent detection of RVF seropositive cases could be explained by the improved sensitivity and specificity of used diagnostic tests, or by a recent introduction of the virus in the country. It could also be linked to the increase in studies assessing the epidemiology of emerging vector-borne viruses in Tunisia and worldwide. In this context, Tunisia

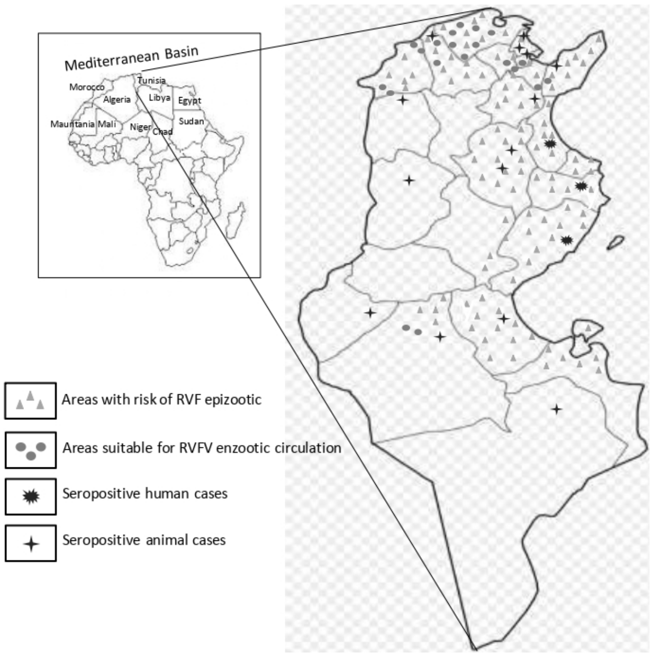

Figure 1: areas with Rift-Valley-fever epizootic risk and areas susceptible to RVF virus enzootic circulation (Arsevska et al., 2016), as well as location of human (Bosworth et al., 2016) and animal seropositive cases (Selmi et al., 2020; Hellal et al., 2021; Kalthoum et al., 2021; Zouaghi et al., 2021), in Tunisia /// *Zones à risque épizootique de fièvre de la vallée du Rift et zones susceptibles de circulation enzootique du virus de la FVR (Arsevska et al., 2016), ainsi que la localisation de cas séropositifs humains (Bosworth et al., 2016) et animaux (Selmi et al., 2020 ; Hellal et al., 2021 ; Kalthoum et al., 2021 ; Zouaghi et al., 2021), en Tunisie*

has been involved in many networks, such as the MediLabSecure network for the surveillance of arboviruses in the Mediterranean and Black Sea regions (Failloux et al., 2017; Pérez-Ramírez et al., 2020). Tunisian laboratories have also participated in several 'external quality assessment' tests for RVF diagnosis. These trials certainly reinforced capacity building and improved RVF diagnosis capacities of involved Tunisian laboratories (Monaco et al., 2015; Pedarrieu et al., 2021).

Risk factors

An epizootic event is characterized by a sudden occurrence of a large number of infected animal cases across a broad area. Undoubtedly, Tunisia is considered to be among countries where the risk of RVF epizootic event is relatively high. Many parameters contribute to this fact. Firstly, RVFV vectors are widely distributed in Tunisia. The presence of numerous vectors such as *Culex theileri, Aedes vexans*, *A. caspius* and *A. detritus* was confirmed, and different Tunisian regions have been described as suitable habitats for these vectors (Arsevska et al., 2016; Moutailler et al., 2008). Secondly, *Culex pipiens* from Tunisia were confirmed to be an efficient vector to transmit experimentally RVFV (Moutailler et al., 2008; Amraoui et al., 2012). Thirdly, climatic factors (temperature and rainfall) combined with the presence of permanent waters and vector distribution can provide opportunities to the RVFV life cycle, particularly in the Northern and Central Eastern regions (Kalthoum et al., 2021; Arsevska et al., 2016). Fourthly, a significant factor associated with the introduction and transmission of RVF is ruminant density, as domestic ruminants and camels act as amplifying RVFV hosts (El Mamy et al., 2011; Arsevska et al., 2016). Sheep are considered the main livestock species in Tunisia with high densities in Northern regions (Arsevska et al., 2016; Mohamed-Brahmi et al., 2010). Camels are mainly found in Southern Tunisia (Arsevska et al., 2016).

Like in other North African countries, Tunisian veterinary services declare that there is no official trade with countries where RVF has been reported (Nielsen et al., 2020b). However, illegal trade and movements of live ruminants between Tunisia and her neighboring countries exist and this situation intensifies during religious periods (Aid El Kebir). This could increase the possibility of RVF introduction into Tunisia, especially with regard to the intensive exchanges with Libya where RVF cases have been recently reported (OIE, 2020).

All reported seropositive cases in Tunisia were located in areas where at least one risk factor has been described. Human RVF seropositive cases reported by Bosworth et al. (2016) were from the Center East (Figure 1), a coastal region known for the presence of lakes and lagoons and where RVF vectors such as *Culex theileri* and *C. pipiens* are present (Arsevska et al., 2016; Pergent and Kempf, 1993). Animal seropositive cases originated from the North, mainly Northwestern regions characterized by high ruminant density and widespread RVF vectors (Zouaghi et al., 2021; Kalthoum et al., 2021) (Figure 1). Seropositive cases have been reported in Central and Central Western Tunisia, regions where ruminant density is relatively high (Hellal et al., 2021) (Figure 1). Regarding camels, seropositive cases were located in the South (Selmi et al., 2020), notably in oases where climatic conditions are optimum for mosquitoes' activity and where ruminant density is high (Arsevska et al., 2016). In addition, live animal movements between Tunisia and neighboring countries are frequent in the region, especially in the context of livestock transhumance (Bouslikhane, 2015).

Tunisia is located in the northeastern part of Africa, a region where epizootic or endemic RVF is confirmed. The country has significant socioeconomic exchanges with Algeria and Libya, two neighboring countries close to RVF endemic regions and where RVF outbreaks have been described, such as the RVF outbreak recently declared in Libya (OIE, 2020); Algeria is close to the Western Sahara, Mauritania, Mali and Niger, where RVF is endemic and many outbreaks have been described (Sow et al., 2014; Javelle et al., 2020; Di Nardo et al., 2014; Faye et al., 2014; Lagare et al., 2019). Border permeability induces uncontrolled animal movements across the Maghreb which could facilitate the spread and establishment of endemic RVF into new areas.

Probable future situation

To date, no RVF outbreak has been reported in Tunisia, and no virus circulation has been confirmed in the country. A large-scale RVF survey has been carried out in 2019 by the General Direction of Veterinary Services in Tunisia (DGSV). More than 4000 ruminants were tested for RVFV antibodies, and all results were negative (data not shown). However, the increasing expansion of RVF into new regions, the detection of seropositive cases and the presence of risk factors in the country raise concern for potential RVF epizootic occurrence and its spread in Tunisia.

In a 2016 study, a map shows suitable areas for the occurrence of RVF in the Maghreb (Morocco, Algeria, Tunisia and Libya) (Arsevska et al., 2016). A multicriteria analysis was assessed integrating host distribution and a combination of ecological factors influencing the distribution and abundance of mosquito vectors (rainfall, temperature, distance to permanent water, altitude and land cover). The relative importance of each risk factor was determined and taken into account in the analysis. Results identified the areas suitable for RVF epizootics to be those most favorable for mosquito habitats with high livestock density. They also showed that, in Tunisia, Northern, Central Eastern regions (i.e. coastal areas) and oases in the South are suitable for an RVF epizootic (Figure 1). Northern regions seem to be moderately suitable for enzootic circulation of the virus (stable and sustained circulation at low or moderate rate), and the South appears little or not suitable (Arsevska et al., 2016) (Figure 1).

The large presence of RVF hosts and vector species, climatic characteristics and geographic location of Tunisia can promote the occurrence of RVF epizootics. The introduction of infected animals into Tunisian herds is probably the most likely path for RVF introduction and outbreak occurrence. Importation of live ruminants from infected countries could also be responsible for the virus spread in Tunisia, as it may have been the case for RVF introduction into the Arabian Peninsula (Abdo-Salem et al., 2011). Another potential factor for the occurrence of the disease in Tunisia is the introduction of infected mosquitoes by air or sea traffic from infected countries (Hartman, 2017). The role of dromedaries cannot be ruled out in the transmission of RVFV. Indeed, the importation of infected camels from Sudan was related to the first outbreak occurrence in Egypt in 1977 (Fawzi and Helmy, 2019). It was described that in specific ecosystems, this animal species can be involved in the viral cycle as an amplifying host. Furthermore, the virus circulated in Mauritanian camels even after the end of an epidemic (Nielsen et al., 2020b).

■ DISCUSSION

Unexpected expansion of many arboviruses has been observed during the last two decades leading to their emergence and/or spread outside their endemic areas; it is notably the case of West Nile virus, Chikungunya virus, Zika virus and RVFV (Kilpatrick, 2011; Mayer et al., 2017). These viruses represent a serious threat to the North African region because of its location and climatic characteristics. Particular attention should be given to RVF since it is a zoonotic infection with a marked impact on the economy as well as on animal and human health.

In the Mediterranean Basin, European countries are not directly exposed to a high risk of RVF introduction. However, the disease spread and introduction of RVFV into new areas have been reported these last years. This raised concern regarding a potential introduction of the virus into Europe. The risk of RVFV introduction into Europe has been assessed to be 'very low' from infected animals, and 'very low' to 'low' from infected vectors introduced by air flight, containers or road transport (Nielsen et al., 2020b). It is recommended to integrate the surveillance systems in place in the European Union for invasive mosquitoes, especially in countries with important sea and air traffic with regions where RVF cases have been described (Nielsen et al., 2020b). An enhanced passive surveillance could be considered the most effective for early detection of RVF introduction. In the European Union, RVF is listed as a Category A disease (Nielsen et al., 2020b), requiring an immediate eradication plan upon detection. Such plan is costly and cannot be applied to countries on the southern bank of the Mediterranean.

The RVF situation is relatively similar in the different North African countries of the Mediterranean Basin, except Libya, where an outbreak was declared in December 2019 (OIE, 2020). In this context, authorities from North African countries should collaborate to implement and harmonize an efficient surveillance system to face any RVF emergence and outbreak. An efficient surveillance system requires strict and rigorous monitoring measures with regard to cross-border animal movements and animal products trade. Special care should be taken to control camel movements since this species could be infected and amplify the virus without any clinical signs.

In Tunisia, in addition to strict border control, an adapted active RVF surveillance must be implemented in regions bordering Libya and Algeria, particularly during high-risk periods (e.g. vector abundance in autumn, after heavy rainfall, at religious festivals). It is important to note that Tunisia does not officially import live animals and animal products either from countries where RVF cases have been reported, or from neighboring countries (Algeria and Libya). Ruminants confiscated by customs are systematically tested for foot-and-mouth disease. Such ruminants are also tested for *peste des petits ruminants* and RVF if suggestive symptoms are detected. Confiscated camels are systematically tested for RVF.

Kalthoum et al. (2021) showed the efficiency of the risk-based surveillance approach, which is the most adapted for countries with relatively limited resources such as Tunisia. This type of approach allows limiting the cost of surveillance by focusing on at-risk areas. Special concerns must be raised when high rates of abortions and/or death in young animals are reported. RVF has been increasingly suspected, especially in abortion cases, and samples have been ever more often taken to the Virology Laboratory for RVF diagnosis. Tunisian health policy-makers should add RVF to the list of abortive diseases systematically investigated in ruminant abortion linked to across-border diseases, for example Q fever. RVF diagnosis techniques have to include VNT in order to have robust and reliable results.

Tunisian authorities should set up a 'One Health' approach to face RVF spread and early detect RVFV introduction or circulation. In this context, a large-scale multidisciplinary study involving virologists, veterinarians, entomologists, epidemiologists and physicians must be conducted. The first step could be at-risk area mapping to determine regions with high and very high RVF risk, where serological surveys should be conducted with relevant detection and confirmation techniques. Other studies are needed to understand better the interactions between RVFV, vectors and hosts in the different ecosystems. Results of all these works will enable to implement efficient surveillance measures in targeted regions and to adapt specific activities of prevention.

An efficient RVF surveillance has to include a system of early detection of virus circulation and/or disease occurrence in animals and humans. Since virus circulation in animals precedes virus transmission to humans, Fawzi and Helmy (2019) emphasized that "it is important to focus on early monitoring of RVFV circulation in animals. Measures, such as systematic screening and quarantine of imported animals could be applied to detect and prevent any infected animal entrance. Strict control measures have to be implemented all along borders to limit and to stop illegal animal movements since the unofficial entry of infected ruminants represents an important risk of RVFV introduction and spread into the country. The implementation of sentinel herds in at-risk areas is recommended to early detect virus circulation in animals." Diagnostic of RVF in humans has to be improved and physicians must think about a possible RVF infection in some cases such as febrile and/or hemorrhagic syndromes, especially in at-risk populations such as slaughterhouse workers, butchers and veterinarians. It is important to note that no vaccine has been yet licensed for human use.

Vector control programs have been based on insecticide use by thermal fogging or ultra-low volume spraying against adult mosquitoes and by applying insecticides to water habitats against immature mosquitoes (Anyamba et al., 2010). However, such measures are often expensive and their effectiveness remains to be proven (Loria et al., 2022). To limit mosquitoes' spread (e.g. *Culex pipiens* and *Aedes vexans*), only a long-term vector control program based on the use of larvicides is recommended, especially, near breeding areas. This achieves high rates of vector control up to 95%, as it has been reported in Europe (Nielsen et al., 2020a). Adulticides are only recommended in case of an outbreak with confirmed human cases because of their environmental side effects (Nielsen et al., 2020b). Vaccination of susceptible animals in at-risk areas could help to prevent RVF spread. However, it is complicated to choose vaccines because they are "either inactivated vaccines with limited efficacy or live attenuated vaccines that could revert to virulence" (Fawzi and Helmy, 2019).

Acknowledgments

The author would like to thank Mrs. Saousen Ben Rached for English revision of the manuscript.

Conflicts of interest

The author declares that there is no conflict of interest.

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Résumé

Mejri S. Fièvre de la vallée du Rift en Tunisie : Synthèse sur la situation actuelle et perspectives

La fièvre de la vallée du Rift (FVR) est une infection zoonotique émergente infectant les humains et les ruminants. L'agent étiologique de cette infection est le virus de la FVR, un arbovirus transmis principalement par les piqûres de moustiques des genres *Aedes* et *Culex*. Durant les deux dernières décennies, des cas de FVR ont été rapportés dans des régions jusque-là indemnes et les épidémies sont devenues de plus en plus fréquentes. De par sa localisation stratégique dans le bassin méditerranéen, la Tunisie a de nombreux échanges avec les autres pays africains ainsi qu'avec l'Europe. L'analyse de la situation épidémiologique de la FVR dans ce pays pourrait aider à comprendre la situation globale de cette infection dans la région méditerranéenne et à élaborer des stratégies efficaces de surveillance à mettre en œuvre dans la région. Dans ce cadre et afin d'étudier l'état des lieux de la FVR en Tunisie, cette synthèse présente une analyse à partir de tous les articles scientifiques traitant de ce sujet dans le pays. La Tunisie est considérée comme à haut risque de propagation de la FVR en raison de sa localisation, de ses caractéristiques climatiques et environnementales, de l'abondance des vecteurs transmettant le virus de la FVR, et de la présence d'espèces animales à risque pour cette maladie. Ainsi, des mesures strictes doivent être prises afin de contrôler et de limiter toute émergence et propagation de la FVR. De telles mesures doivent inclure le contrôle des mouvements des animaux (particulièrement aux frontières), le contrôle des espèces vectrices du virus, et le perfectionnement des outils de diagnostic pour la détection précoce de tout cas suspect. L'implémentation d'une approche « Une seule santé » multidisciplinaire serait l'une des meilleures solutions pour faire face aux maladies zoonotiques à transmission vectorielle comme la FVR.

Mots-clés : virus de la fièvre de la vallée du Rift, épidémiologie, facteur de risque, Tunisie

Resumen

Mejri S. Fiebre del valle del Rift en Túnez: Síntesis de la situación actual y perspectivas

La fiebre del valle del Rift (FVR) es una infección zoonótica emergente que infecta a humanos y rumiantes. El agente etiológico de esta infección es el virus de la FVR, un arbovirus transmitido principalmente por la picadura de mosquitos de los géneros *Aedes* y *Culex*. Durante las dos últimas décadas se han identificado casos de FVR en zonas anteriormente indemnes, además las epidemias son cada vez más frecuentes. Debido a su situación estratégica en la cuenca mediterránea, Túnez mantiene numerosos intercambios con otros países africanos, así como con Europa. El análisis de la situación epidemiológica de la FVR en este país podría ayudar a comprender la situación general de la infección en la región mediterránea y a desarrollar estrategias de vigilancia eficaces. En este contexto y con el fin de estudiar la situación de la FVR en Túnez, esta síntesis presenta un análisis basado en todos los artículos científicos que tratan el tema en el país. Se considera que Túnez tiene un alto riesgo de propagación de la FVR debido a su ubicación, sus características climáticas y medioambientales, la abundancia de vectores transmisores el virus de la FVR y la presencia de especies animales susceptibles de desarrollar la infección. Por lo tanto, deben tomarse medidas estrictas para controlar y limitar la aparición y propagación de la FVR. Dichas medidas deben incluir el control de los movimientos de animales (especialmente en las fronteras), el control de las especies vectoras del virus y el perfeccionamiento de las herramientas de diagnóstico para la detección precoz en caso de duda. La aplicación del enfoque multidisciplinar «Una sola salud» sería una de las mejores soluciones para hacer frente a las enfermedades zoonóticas de transmisión vectorial, como la FVR.

Palabras clave: virus de la fiebre del Valle del Rift, epidemiología, factores de riesgo, Túnez