**Name of Journal:** *World Journal of Transplantation*

**Manuscript NO:** 53520

**Manuscript Type:** REVIEW

**Emerging and neglected zoonoses in transplant population**

Mrzljak A *et al.* Emerging/neglected zoonoses and transplant

Anna Mrzljak, Rafaela Novak, Nenad Pandak, Irena Tabain, Lucija Franusic, Ljubo Barbic, Maja Bogdanic, Vladimir Savic, Danko Mikulic, Jadranka Pavicic-Saric, Vladimir Stevanovic, Tatjana Vilibic-Cavlek

**Anna Mrzljak,** Department of Medicine, Merkur University Hospital, Zagreb 10000, Croatia

**Anna Mrzljak, Rafaela Novak,** School of Medicine, University of Zagreb, Zagreb 10000, Croatia

**Nenad Pandak**, Depatment of Medicine, The Royal Hospital Muscat, Muscat 111, Oman

**Irena Tabain,** Department of Virology, Croatian Institute of Public Health, Zagreb 10000, Croatia

**Lucija Franusic,** General Hospital Dubrovnik, Dubrovnik 20000, Croatia

**Ljubo Barbic,** Department of Microbiology and Infectious Diseases with Clinic,Faculty of Veterinary Medicine, University of Zagreb, Zagreb 10000, Croatia

**Maja Bogdanic,** Department of Virology, Croatian Institute of Public Health, Zagreb 10000, Croatia

**Vladimir Savic,** Poultry Center,Croatian Veterinary Institute, Zagreb 10000, Croatia

**Danko Mikulic**, Department of Abdominal and Transplant Surgery, Merkur University Hospital, Zagreb 10000, Croatia

**Jadranka Pavicic-Saric,** Department of Anestesiology and Intensive Medicine, Merkur University Hospital, School of Medicine, University of Zagreb, Zagreb 10000, Croatia

**Vladimir Stevanovic**, Department of Microbiology and Infectious Diseases with Clinic, Faculty of Veterinary Medicine, University of Zagreb, Zagreb 10000, Croatia

**Tatjana Vilibic-Cavlek,** Department of Virology, Croatian Institute of Public Health; School of Medicine, University of Zagreb, Zagreb 10000, Croatia

**Author contributions:** Mrzljak A and Vilibic-Cavlek T made contributions to conception and design of the study, involved in drafting and revising the manuscript critically; Novak R, Pandak N, Tabain I, Franusic L, Bogdanic M, Barbic L, Savic V, Mikulic D, Pavicic-Saric J and Stevanovic V were involved in collecting data and drafting the manuscript; all authors read and approved the final manuscript.

**Corresponding author:** **Anna Mrzljak, FEBG, MD, PhD, Associate Professor,** Department of Medicine, Merkur University Hospital, Zajceva 19, Zagreb 10000, Croatia. [anna.mrzljak@mef.hr](mailto:anna.mrzljak@mef.hr)

**Received:** December 22, 2019

**Revised:** March 15, 2020

**Accepted:** March 22, 2020

**Published online:**

**Abstract**

Zoonoses represent a problem of rising importance in the transplant population. A close relationship and changes between human, animal and environmental health ('One Health' concept) significantly influence the transmission and distribution of zoonotic diseases. The aim of this manuscript is to perform a narrative review of the published literature on emerging and neglected zoonoses in the transplant population. Many reports on donor-derived or naturally acquired (re-)emerging arboviral infections such as dengue, chikungunya, West Nile, tick-borne encephalitis and Zika virus infection have demonstrated atypical or more complicated clinical course in immunocompromised hosts. Hepatitis E virus has emerged as a serious problem after solid organ transplantation (SOT), leading to diverse extrahepatic manifestations and chronic hepatitis with unfavorable outcomes. Some neglected pathogens such as lymphocytic choriomeningitis virus can cause severe infection with multi-organ failure and high mortality. In addition, ehrlichiosis may be more severe with higher case-fatality rates in SOT recipients. Some unusual or severe presentations of borreliosis, anaplasmosis and rickettsioses were also reported among transplant patients. Moreover, toxoplasmosis as infectious complication is a well-recognized zoonosis in this population. Although rabies transmission through SOT transplantation has rarely been reported, it has become a notable problem in some countries. Since the spreading trends of zoonoses are likely to continue, the awareness, recognition and treatment of zoonotic infections among transplant professionals should be imperative.

**Key words:** Zoonoses; Solid-organ transplant; Vector-borne diseases; Non-vector borne diseases; Virus; Bacteria; Parasite

Mrzljak A, Novak R, Pandak N, Tabain I, Franusic L, Barbic L, Bogdanic M, Savic V, Mikulic D, Pavicic-Saric J, Stevanovic V, Vilibic-Cavlek T. Emerging and neglected zoonoses in transplant population. *World J Transplant* 2020; In press

**Core tip:** The importance of zoonotic diseases in the transplant population is rising. Given the current diversity and extent of zoonotic pathogens, modes of transmission and clinical presentation in immunocompromised hosts, this manuscript aims to summarize the published literature on emerging and neglected zoonoses in the transplant population.

**INTRODUCTION**

Zoonotic diseases - transmitted and shared between animals and humans, are nowadays receiving increased recognition. WHO estimates that more than 60% of all human pathogens are zoonotic, and that they represent 75% of all emerging pathogens during the past decade[1]. They encompass a wide range of pathogens (viruses, bacteria, parasites) and modes of transmission: *via* direct contact with infected animals or their secretions, the bite of arthropod vectors or indirect contact *via* the environment[2]. Given a close relationship between human, animal and environmental health (the 'One Health' concept), human activities, climate and landscape changes influence significantly transmission and distribution of zoonoses[3,4]. The number of zoonotic diseases has been increasing in the last two decades and the spreading trends are likely to continue in future years. For example, West Nile virus (WNV), one of the most widely distributed arboviruses has expanded its area of circulation in many European countries[5]. In 2018, a large outbreak occurred across Southern and Central Europe with the number of confirmed human cases increasing up to 7.2-fold from the previous transmission season[6]. A total of 2083 human cases and 285 outbreaks among equids were reported, including previously virus-free regions[7]. In addition, geographical distribution of Zika virus (ZIKV) has steadily expanded. In 2015 and 2016, large outbreaks of ZIKA occurred in the Americas. In the USA and US Territories, 5168 and 36512 symptomatic ZIKV disease cases were reported in 2016[8]. Hepatitis E virus (HEV) is an important cause of acute viral hepatitis worldwide, with an increasing incidence in Europe since 2010. The reported incidence over 10 years has grown by ten times: From 514 cases in 2005 to 5617 cases in 2015[9]. On the other hand, solid-organ transplant (SOT) population is expanding as a result of increasing transplant rates, improved post-transplant management and survival[10,11]. In comparison to immunocompetent hosts, immunocompromised state of SOT recipients is an inevitable additional risk for the infection and unfavorable outcomes due to atypical presentation, possible delay in diagnostic tests (serology), more frequent presence of disseminated/advanced disease and prolonged treatment. Although majority of zoonotic infections develop in the post-transplant period, donor or transfusion transmitted zoonotic infections have been increasingly acknowledged as well. Therefore, the increasing trend of reports on zoonotic diseases in the transplant population over the past decade substantiates a need for a comprehensive review. This narrative review will cover two main groups of zoonotic infections; vector and non-vector borne infections and focus on major pathogens and their clinical manifestations in the transplant population (Table 1).

**VECTOR-BORNE ZOONOSES**

***Tick-borne encephalitis virus***

Tick-borne encephalitis virus (TBEV) is a tick-borne flavivirus widely distributed from Europe through far-eastern Russia to Japan. The virus is maintained in cycles involving *Ixodid* ticks (*Ixodes ricinus* and *Ixodes persulcatus*) and wild vertebrate hosts (mainly rodents)[12]. Transmission to humans occurs most commonly through a bite of an infected tick, however approximately 1% of all TBE cases are thought to be caused by food-borne TBEV (consumption of raw goat milk)[13,14]. TBEV can cause a wide spectrum of the disease, ranging from asymptomatic infection to severe encephalitis and even death[14]. Diagnosis is usually confirmed by the detection of TBEV IgM and IgG antibodies in serum and cerebrospinal fluid (CSF) samples. Determination of IgG avidity may be helpful in cases of atypical antibody response[15]. There are very few data on the transplant-transmitted TBEV infection. In 2012, a cluster of fatal TBEV infection was reported in Poland. Transmission of TBEV occurred through the transplanted organs (liver, kidneys) from a single donor to three recipients. The donor lived in an endemic area and the presence of TBEV was confirmed by the same viral strain detected in all recipients and in the donor[16]. Although transmission of TBEV through organ transplantation is rare, clinicians should consider screening donors who live or have recently visited endemic areas for TBEV, particularly during the arbovirus transmission season.

***Borrelia burgdorferi (Lyme disease)***

*Borrelia burgdorferi* is a tick-borne zoonosis widely distributed in North America and Europe. All three pathogenic species, *B. burgdorferi*, *B. afzelii* and *B. garinii* occur in Europe, and the latter two have been identified in Asia. *Borrelia burgdorferi* circulates between [*Ixodes*](https://en.wikipedia.org/wiki/Ixodes) ticks and [vertebrate](https://en.wikipedia.org/wiki/Vertebrate) hosts in an [enzootic cycle](https://en.wikipedia.org/wiki/Sylvatic_cycle). Ticks can transmit borrelia to humans, but humans are dead-end hosts, unlikely to continue the life cycle of the spirochete[17]. Lyme disease (LD) has a broad spectrum of clinical manifestations. Primary infection presents as erythema migrans (EM). Late stages occur weeks to years following infection and include arthritis, peripheral neuropathy, and skin ﬁndings such as acrodermatitis chronica atrophicans[18]. Neuroborreliosis is one of the manifestations of LD involving the central nervous system (CNS)[19]. The role of immunosuppression in the development and progression of LD is not well understood. An analysis of SOT recipients on immunosuppressive treatment who presented with solitary EM did not reveal any signiﬁcant differences in the clinical course of infection as compared with the general population[20]. The first case of LD in a transplanted patient was described in 1993 in a kidney transplant recipient in whom the disease progressed into the disseminated stage with severe neurological signs[21]. A study from Slovenia presented a case series of six SOT recipients with EM. All six patients had solitary skin lesions with clinical characteristics comparable to those of the skin lesions in immunocompetent patients. No clinical signs or symptoms suggesting borrelia dissemination were present or were reported either during the initial course of the illness or during the one-year follow-up period after antibiotic treatment and persistence of borrelia organisms in the skin after treatment was not established[20]. A case report of Lyme carditis after liver transplant that progressed to disseminated illness with a concomitant heart block and deterioration of mental status has also been described[22].

***Anaplasma phagocytophilum (Human granulocytic anaplasmosis)***

Human granulocytic anaplasmosis (HGA) is a tick-borne infection caused by *Anaplasma phagocytophilum*, an intracellular bacterium, which commonly infects neutrophils[23]. The infection is mostly spread through a bite of *Ixodes* ticks in Europe (*Ixodes ricinus* and *Ix. persulcatus*) and in North America (*Ix. scapularis* and *Ix. pacificus*) after feeding on infected animals such as domestic (dog, horse) and wild ruminants, hedgehogs and wild boars[24,25]. However, there are reports of transmission through infected blood as well as of perinatal transmission[25]. Immunocompetent individuals with HGA develop high-grade fever, malaise, nausea, headache, myalgia, arthralgia, CNS and gastrointestinal symptoms. Rarely individuals present with an erythematous rash[26]. Whereas anaplasmosis is mostly a self-limiting disease, predictors of a more severe course include advanced age, immunosuppression, and comorbidities such as diabetes[26]. Severe course includes the development of acute respiratory distress syndrome, peripheral neuropathies, DIC-like coagulopathies, hemorrhagic manifestations, rhabdomyolysis, pancreatitis and acute renal failure[26]. The diagnosis can be confirmed by microscopic identification of morulae in neutrophils on peripheral blood smear or in buffy coat, PCR or serology[27]. Based on the few case reports of anaplasmosis in recipients of kidney, pancreas or liver[28-32] the incidence of anaplasmosis in transplant recipients does not appear to be high and manifestations of the disease seem to be similar to non-transplant patients. In transplant patients, the clinical presentation commonly involved non-specific systemic symptoms. However, there was also a rather unusual presentation in a kidney recipient in the form of orchitis[33]. It was observed that immunosuppressive therapy does not seem to alter acute or convalescent antibody titers[34]. Solid organ transplant (SOT) recipients with anaplasmosis usually also have a good initial response to treatment with doxycycline[33].

***Ehrlichia spp. (Human monocytic ehrlichiosis)***

Human monocytic ehrlichiosis (HME) is a tick-borne zoonosis caused by *Ehrlichia chaffeensis* and less commonly, *E. ewingii.* HME occurs across the south-central, south-eastern, and mid-Atlantic states, corresponding to areas where their reservoirs (white-tailed deer) and vectors (*Amblyomma americanum* ticks) both exist[35]. The clinical manifestations of HME vary from a self-limited febrile illness to fatal multi-organ failure[25]. Severe manifestations such as acute respiratory distress syndrome, pulmonary hemorrhages, meningoencephalitis, toxic shock-like, and septic shock-like syndromes have also been described[25,36,37].The diagnosis can be confirmed by PCR or serology[25,38]. In some cases, morulae may be observed in leukocytes on Wright stained peripheral blood smear, particularly in immunocompromised hosts[25,39].There have been reports of HME transmission through SOT[37], as well as through blood product transfusions[25].Ehrlichiosis was described in kidney[37,40-44], liver[36,43,45], lung[38,42,43,46] and heart transplant recipients[42,43]. Immunocompromised persons, particularly SOT recipients, more frequently develop severe and prolonged manifestations of ehrlichiosis with higher case-fatality rates[25,37,42]. Furthermore, SOT recipients showed having a higher risk to develop acute lung injury and acute respiratory distress syndrome[42]. However, one report showed that 15 transplant patients with ehrlichiosis had similar and favorable outcomes compared with immunocompetent patients[43]. Among SOT recipients, infected lung recipients showed more severe and progressive clinical course[42]. Some reports, have also described re-infections in liver transplant recipients, suggesting that initial infection may not provide long-lasting immunity in patients on immunosuppressive therapy[45].

***Rickettsia spp.***

Rickettsioses are bacterial infectious diseases that occur in endemic areas across the world. They are classified into two main groups: The spotted fever group with the main representatives; *Rickettsia rickettsii* (Rocky Mountain spotted fever; RMSF) transmitted by the ticks in the USA, Mexico and South America[47]; *R. conorii* (Mediterranean spotted fever; MSF) transmitted by dog ticks in Southern and Eastern Europe, Africa, India, Russia[47,48] and the typhus group which includes *R. prowazekii* (epidemic typhus) and *R. typhi* (murine typhus)[48]. Following a tick exposure, clinically significant rickettsial infections present with flu-like symptoms with or without eschar at the site of the tick bite, accompanied by rash. The clinical course is highly variable and ranges from self-limited to vasculitis-mediated organ failure and death[49]. The diagnosis of rickettsioses is most often established by serology. Indirect immunofluorescence assay (IFA) has been considered the gold standard. The test has limited utility in species determination within a serogroup due to extensive cross-reactivity and as any immunoglobulin-based assay in the context immunocompromised patient should be interpreted with caution[49]. Rickettsioses have been rarely reported in the transplant population. The scarcity of the data implies that even in immunocompromised hosts majority of the infections are mild and rarely result in a malignant vasculitis-associated form. A case of RMSF in a cardiac transplant recipient from southern Utah demonstrated a prompt clinical response after empirical treatment with doxycycline and delayed development of rickettsia antibodies (5 mo after the infection)[50]. Only one case demonstrated the development of complications. Severe MSF infection has been reported in a kidney transplant recipient from Southern France, who developed flu-like symptoms, maculopapular rash and splenic rupture requiring splenectomy. Doxycycline therapy resulted in rapid improvement and favorable outcome[51]. Rickettsial infections are probably underrecognized and underreported in the transplant population.

***Orientia tsutsugamushi******(Scrub typhus)***

Scrub typhus is a zoonosis caused by *Orientia tsutsugamushi*, an obligate intracellular bacterium. It is a common re-emerging rickettsial infection in India and many other countries in Southeast Asia, the Pacific Islands, and Northern Australia (the "tsutsugamushi triangle")[52]. *Orientia tsutsugamushi* is transmitted to humans by the bites of the larval life stage of infected *Leptotrombidium* mites (*Leptotrombidium deliense* and *Leptotrombidium akamushi*) while field rodents serve as reservoirs. The clinical presentation of scrub typhus ranges from nonspecific febrile illness to potentially fatal multi-organ involvement such as liver, kidney, or lung[53]. In some patients, an eschar may develop at the site of mite feeding. CNS involvement (meningitis, encephalitis) has also been observed[54]. The diagnosis of scrub typhus is usually made by a single IFA titer against *O. tsutsugamushi* of 400, a seroconversion or a 4-fold increase in IgG titer using paired serum samples[55]. So far, only one study described scrub typhus in a renal transplant recipient in India. The patient presented with fever, headache, meningeal signs, graft dysfunction, and eschar and responded well to intravenous azithromycin and became afebrile within 24 h[53]. Since many cases of scrub typhus are underdiagnosed, clinicians should consider in differential diagnosis this potentially fatal zoonosis in regions of endemicity.

***Rift Valley fever virus***

Rift Valley fever virus (RVFV) is a mosquito-borne phlebovirus. RVFV outbreaks in humans have been reported in Africa, the Indian Ocean islands, and the Arabian Peninsula[56]. Cattle, sheep, goats, and camels are particularly susceptible to RVF and serve as amplifying hosts for the virus[57]. RVFV transmission to humans occurs by direct contact with infected animals or their body fluids, consumption of raw milk or meat or by mosquito bites (*Culex, Aedes*)[58]. Human infections are usually subclinical or presenting as moderate to severe febrile illness while 1-2% of RVFV infections result in fatal haemorrhagic fever[59]. RVFV can be diagnosed by RNA detection, antigen detection or serology[60]. In 2015, an imported case of RVF in a kidney transplant recipient was reported in France. The initial clinical presentation was characteristic for acute hepatitis and four weeks later, the patient presented with a meningoencephalitis. IgM and IgG antibodies were detected in CSF and blood up to 2 mo after symptoms onset, whereas in urine and semen, RVFV RNA was detected by RT-PCR up to three and four mo, respectively. The severity of clinical presentation may have been related to immunosuppression, which might also have slowed down the clearance of the virus[61].

***St. Louis encephalitis virus***

St. Louis encephalitis virus (SLEV) is a mosquito-borne flavivirus. The virus can be found in the Western Hemisphere, but epidemics typically occur in the Ohio River-Mississippi River basin. Humans are dead-end hosts of a mosquito–bird–mosquito cycle[62]. While mostly asymptomatic, less than 1% of all SLEV infections lead to symptomatic disease ranging from febrile illness to aseptic meningitis or encephalitis[63]. Diagnosis is based on serology[64]. The prevalence of SLEV infections in transplant recipients is largely unknown. During the 2015 outbreak, three SOT recipients were hospitalized with confirmed neuroinvasive SLEV infection (meningoencephalitis) in Phoenix, Arizona. One patient died, whereas two other patients survived but required prolonged hospitalization. One patient recovered fully; the other patient had residual dysarthria[65].

***ZIKV***

ZIKV is an emerging mosquito-borne flavivirus. Before the large outbreak of ZIKV infection on Yap Island (Federated States of Micronesia), only sporadic cases were reported in Africa and Asia, but in 2007 ZIKV emerged as an important human pathogen[66,67]. Human infections mainly occur through the bite of *Aedes* mosquitoes (*Ae. aegypti* and *Ae. albopictus)*, however, non-vector borne transmission of ZIKV such as sexual and transplacental transmission was also reported[68]. Although symptoms associated with ZIKV infection are generally mild and the majority of infected persons do not develop any symptoms, ZIKV is also associated with severe neurological disorders, mainly Guillain-Barré syndrome. Diagnostic testing for ZIKV infection can be accomplished using molecular and serologic methods[69,70]. Case reports describing ZIKV infection in transplant patients are limited. In 2015 and 2016, ZIKV infection was confirmed among 129 kidney transplants and 58 liver transplants tested in Brazil. All ZIKV-infected SOT recipients presented with complications, notably bacterial infections, and required hospitalization. Based on this small case series, it was not possible to assess the potential impact of ZIKV in the immunosuppressed SOT recipients, including infectious complications and graft rejection[71]. Therefore, further studies are needed to evaluate the impact of ZIKV infection in this population group.

***Chikungunya virus***

Chikungunya virus (CHIKV) is an emerging mosquito-borne alphavirus. Since 2004, CHIKV caused several large outbreaks in Africa, the Indian Ocean islands, Asia, Europe, and the Americas[72]. In an urban transmission cycle, humans are the major hosts and mosquitoes of the genus *Aedes* are vectors[73]. Although chikungunya fever is usually benign, prolonged polyarthralgia may lead to considerable disability in a significant proportion of patients[72]. Atypical manifestations include meningoencephalitis, myocarditis, respiratory, renal and hepatic failure[74,75]. Laboratory diagnosis is accomplished by detection of CHIKV RNA and/or detection of IgM and IgG antibodies[72]. Few data exist regarding the clinical characteristics of CHIKV infections in the transplant population[76-79]. In one case series of SOT recipients from Colombia with confirmed CHIKV infection, most patients had a benign clinical course with no severe complications[78]. A study from Brazil analyzed clinical symptoms of chikungunya in four kidney transplant recipients. The clinical picture was typical, none of patients developed any severe manifestations and all recovered fully with no complications[77]. Another Brazilian study showed similar results. SOT recipients with CHIKV infection seem to have a clinical presentation and course similar to those seen in the general population, with no apparent damage to the graft. Among liver transplant recipients, elevation of liver enzymes was not observed, and there was no clinical impact on graft function. Among kidney transplant recipients, only a few had a slight increase of serum creatinine levels, without acute kidney failure or dialytic support[80]. Although reports on the chikungunya in the transplant population are rare, the transplant community must be reminded that the risk of CHIKV infection should be considered in deceased organ donor candidates recently returned from travel to endemic areas[76].

***Dengue virus***

Dengue virus (DENV) is a mosquito-borne flavivirus widely distributed in the tropics and subtropics. In an urban cycle, the virus is transmitted from human to human by the bite of *Ae. aegypti* and *Ae. albopictus* mosquitoes. Non-vectorial DENV transmission through SOT can also occur[81]. The clinical presentations of DENV infection range from asymptomatic to severe illness with fatal outcome. The symptomatic cases are categorized as undifferentiated febrile illness, dengue fever, dengue hemorrhagic fever and dengue shock syndrome[82]. Etiologic diagnosis can be obtained by virus isolation, detection of NS1 antigen, DENV RNA or specific IgM and IgG antibodies[83]. SOT recipients showed a spectrum of clinical manifestations similar to the non-transplant population. However, the course of the illness can be prolonged with complications such as graft dysfunction. Fatal cases were also reported[84-86]. A Thai study analyzed outcomes of DENV infection in a large cohort of kidney transplant recipients. Although a transient decline in allograft function occurs in some patients, the overall clinical and allograft outcomes seemed to be favorable[87]. A Colombian study on retrospective case series of SOT recipients with DENV infection showed that regarding the clinical course, 75% of patients had at least one warning sign, 45% were managed in the intensive care unit, and 30% had severe dengue. However, all patients had a full recovery after the infection[88]. In contrast, a study from India showed that early post-transplant DENV infection appears to be severe and associated with more complications in kidney transplant recipients[89]. There have been limited descriptions of possible DENV transmission through SOT, of which the majority are classified as possible transmission due to the lack of DENV RNA confirmation in the donor[81,90,91]. A case of DENV transmission from donor to the recipient after liver transplantation was described in India. The recipient developed dengue fever without showing any features of severe graft dysfunction and recovered fully[81]. Several studies in SOT recipients who developed dengue through organ transplantation showed that the liver was the main target organ in all patients, even in subjects that received heart and kidney transplantation. Transplant patients were more likely to present with elevated liver transaminases and hyperbilirubinemia, suggesting that the liver could be more susceptible to DENV or is generally more compromised in transplant recipients[81,91,92]. A recently published study from India presented the first report on the detection of DENV in the donor cornea indicating the risk of iatrogenic DENV transmission through corneal transplantation[93]. To avoid DENV transmission by organ or tissue transplantation, the donors should be screened in endemic areas.

***WNV***

WNV is one of the most widely distributed emerging mosquito-borne flaviviruses. In a natural cycle, the virus is maintained in a bird-mosquito-bird cycle. Transmission to humans occurs through the bite of *Culex* mosquitoes[94]. Approximately 80% of immunocompetent individuals infected with WNV remain asymptomatic while 20% develop mild febrile disease (WNV fever). Less than 1% of infected individuals, mainly immunocompromised and elderly develop neuroinvasive disease (meningitis, encephalitis, myelitis)[95]. Diagnosis is confirmed by the detection of WNV IgM and IgG antibodies in serum/CSF with confirmation by virus neutralization test in samples with cross-reactive antibodies[96]. Since WNV IgM antibodies may persist up to 500 d in some patients, IgG avidity differentiates current/recent WNV infection from persistent IgM seropositivity from the previous WNV transmission season[97]. WNV RNA can be detected in blood, CSF and urine samples using RT-PCR, but molecular methods are less sensitive than serology[98]. WNV has been identified as a cause of both donor-derived and post-transplant infection[99]. WNV transmission by organ transplantation was first reported in 2002[100]. Thereafter, there are many reports on donor-derived or naturally acquired WNV infection in the adult transplant population[101-108]. Although WNV infection is associated with higher mortality in the transplant patients[105,108,109] there are some reports on WNV in SOT recipients with a complete recovery as well as asymptomatic infections[108,110]. Few reports describing post-transplant WNV neuroinvasive disease in pediatric patients showed a complete recovery in all patients[104,111,112]. In the light of the WNV (re-) emergence, clinicians should be aware that SOT recipients could be exposed to WNV *via* multiple sources**.** Therefore, WNV should be included in the differential diagnosis in all patients presenting with fever and neurological symptoms after transplantation during the arbovirus transmission season.

***Usutu virus***

Usutu virus (USUV) is a mosquito-borne flavivirus that emerged in Europe in 1996[113]. The natural cycle, geographic distribution and clinical symptoms of USUV overlap with WNV. Although human clinical cases of USUV infection are rarely reported, several recently published reports highlight its role in the etiology of neuroinvasive diseases[114-117]. Like WNV, the majority of USUV infections are asymptomatic or present as a non-specific febrile disease (USUV fever)[117]. Neuroinvasive disease was reported in both immunocompetent and immunocompromised patients in Italy, Croatia, and Hungary[114,116,118,119]. In addition, some atypical presentations such as facial paresis have also described[120]. However, there is only one published report on USUV infection in a transplanted patient in Italy. The patient who underwent an orthotopic liver transplant developed neuroinvasive disease in the post-transplant period[121]. Since many of USUV cases remain underdiagnosed or misdiagnosed as WNV due to similar clinical symptoms and serological cross-reactivity, clinicians should keep in mind this viral zoonosis, especially during the arbovirus transmission season.

***Eastern equine encephalitis virus***

Eastern equine encephalitis virus (EEEV) is a mosquito-borne alphavirus endemic to eastern North America. In nature, the virus spreads between *Culiseta melanura* mosquitoes found in forested wetlands. Mosquitoes of *Aedes* and *Culex* genera may transmit EEEV to humans[122].Most persons infected with EEEV are asymptomatic or they present with a non-specific febrile illness, while less than < 5% develop neuroinvasive disease (meningitis, encephalitis). The case fatality rate is around 50% and many survivors suffer residual neurological sequelae[123].There is only one report of organ-derived EEEV. In autumn 2017, three SOT recipients (lung, heart, liver) from a common donor developed encephalitis one week after transplantation. Lung and liver recipients died, while the heart recipient survived but had residual tremor. The donor and all organ recipients showed laboratory evidence of EEEV. The fact that all SOT recipients developed encephalitis suggests that the risk of neuroinvasive disease may be increased with this route of transmission. EEEV should be considered in SOT recipients who develop encephalitis after transplantation, particularly if donors and recipients reside in endemic areas of the USA[124].

***Leishmania spp.***

Leishmaniasis is a cosmopolitan zoonosis caused by the protozoan parasite of the genus *Leishmania*. It is transmitted by the bite of phlebotomine sandflies of the genus

*Phlebotomus* (in the Old World) or *Lutzomyia* (in the New World). So far, at least 20 different *Leishmania* species have been associated with human infection. Clinical presentation of leishmaniasis includes cutaneous (CL), mucocutaneous (MCL), or visceral leishmaniasis (VL)[125]. CL occur in three different forms: Localized, diffuse and disseminated. CL is characterized by single or multiple skin ulcers, satellite lesions, or nodular lymphangitis. MCL present with mucosal tissue metastasis in the mouth and upper respiratory tract *via* lymphatic or hematogenous dissemination. VL is the most severe form of leishmaniasis and if untreated it is fatal in 95% of patients[125,126]. VL is usually caused by *Leishmania donovani* or *L. infantum* although other *Leishmania* species that usually cause CL have been described causing VL too[125]. Clinical presentation of VL is nonspecific with prolonged fever, anorexia, weight loss and overall poor health status. Typically the patients have hepatosplenomegaly and lymphadenopathy and in laboratory examination pancytopenia is frequently found[127]. The worldwide number of VL cases in SOT recipients has steadily increased since the 1990s, although VL is still a rare disease among transplant recipients[128]. VL is the most frequently observed clinical presentation in this population, followed by MCL and more rarely CL. Fever is the most common symptom of VL in SOT recipients, whereas organomegaly may be less frequent in SOT recipients than in immunocompetent individuals. Immunosuppression seems to predispose to development of MCL caused by viscerotropic strains[128-130]. Clinical presentation in these patients is almost the same as in immunocompetent persons although sometimes it can be atypical making it much more difficult for the diagnosis, therefore it is frequently overlooked or delayed in transplant patients. The combination of conventional and molecular diagnostic methods may serve as the best approach[130].

**NON-VECTOR-BORNE ZOONOSES**

***Hepatitis E virus***

HEV is a non-enveloped RNA virus that belongs to the family *Hepeviridae*. Genotypes 1 and 2 are restricted to humans only, while 3 to 8 are zoonotic genotypes. In fragile sanitary infrastructure (e.g. Asia, Africa, Mexico) genotypes 1 and 2 usually cause human diseases, whereas genotypes 3 and 4 are nowadays found to be the most common genotypes in high-income countries[131]. Waterborne, zoonotic and foodborne transmissions are the most common routes of infection, with the primary reservoirs (Europe) being domestic pigs, wild boars, and deer[131]. Parenteral transmission, transmission *via* solid organs and blood components has been increasingly recognized[131,132]. HEV is diagnosed through serology and nucleic acid amplification test, although, only HEV RNA testing is recommended for the immunocompromised population[131]. Hepatitis E virus infection typically manifests as an acute self-limiting hepatitis, but may also present as fulminant hepatitis (pregnant women) or acute-on–chronic liver failure in patients with pre-existing liver diseases or extra-hepatic manifestations[131,132]. After solid-organ transplantation, genotype 3 and 4 HEV can be responsible for chronic hepatitis (positive HEV RNA > 6 mo) where the majority of cases are asymptomatic accompanied by mild liver test abnormalities. Chronic infections may rapidly progress to liver fibrosis and cirrhosis[133]. Thus far, there have been numerous reports of chronic hepatitis E in the liver, kidney, heart, lungs, liver-kidney, kidney-pancreas, islet cell recipients[133,134]. Furthermore, extrahepatic manifestations are also common in SOT recipients, including neurological (neuralgic amyotrophy, Guillain-Barré syndrome, encephalitis, myelitis)[135], renal manifestations (membranoproliferative and membranous glomerulonephritis)[136], as well as thrombocytopenia[135] and cryoglobulinemia[136]. After an acute infection, one third of the patients will clear the virus after the reduction of immunosuppression[131]. In other patients (about 60%), the infection will typically progress to chronic forms and lead to the need for additional treatments[131,133]. A recent multi-center study which included 255 solid organ transplant recipients, confirmed that ribavirin is highly efficient for treating chronic HEV infection and that HEV RNA polymerase mutations do not play a role in HEV clearance[137].

***Rabies***

Rabies virus (RABV) is a neurotropic lyssavirus that belongs to the family *Rhabdoviridae*. With some exceptions (particularly islands), the RABV is found worldwide, however almost all human deaths caused by RABV occur in Asia and Africa. Typical reservoirs of RABV are domestic dog (Africa and Asia), jackal (Africa), mongoose (Africa), fox (Europe, Asia, America), raccoon (America), skunk, coyote (America) and bats (Europe, Australia, America). Humans become infected by the bite of infected animals or by contact with infectious saliva through mucous membranes or breaks in the skin[138]. Human-to-human RABV transmission may occur through tissue or organ transplantation. The first case of RABV transmitted through corneal transplantation was reported in 1978 in the USA[139], followed by several other reports[140-142]. However, rabies transmission through SOT transplantation has rarely been reported. In 2004 (USA), four recipients of a liver, kidneys and an arterial segment from a common organ donor with unrecognized rabies developed encephalitis within 30 d after transplantation. The patients presented with fever and altered mental status (confusion, agitation, tremors, and delirium). All patients died within 50 d after transplantation[143]. In 2013, a patient died of rabies 18 mo after receiving a deceased-donor kidney transplant in the USA. Three other recipients (kidney, heart, and liver) did not show symptoms consistent with rabies or encephalitis. All received post-exposure prophylaxis with rabies immune globulin and vaccine and remain asymptomatic[144]. The transmission of RABV through SOT has become a notable problem in China. In 2015, two patients who received kidney transplants from the same donor presented with typical symptoms of rabies and eventually died. In 2016, infected donor organs were transplanted to three patients. Two recipients that were diagnosed with rabies died[145]. In 2016, another two cases of RABV transmission through SOT were reported in China. Two kidney transplant recipients died, whereas a liver recipient did not show any signs or symptoms of rabies or encephalitis[146]. A case of RABV transmission through a kidney transplant was also reported in a child in Kuwait[147]. Since the mortality rate of rabies is extremely high, rabies should be considered in patients with acute progressive encephalitis of unexplained etiology, especially for potential organ donors[144].

***Lymphocytic choriomeningitis virus***

Lymphocytic choriomeningitis virus (LCMV) is an Old World arenavirus distributed in Europe and Americas. The main reservoir of LCMV is a house mouse (*Mus musculus, Mus domesticus*), but some other rodents including pet animals may also transmit the virus[148]. LCMV transmission to humans occurs by inhalation of aerosolized excreta/secreta of infected rodents (urine and saliva), bites and contact with rodent blood[149]. LCMV infection in immunocompetent individuals is typically asymptomatic or it presents as nonspecific febrile illness or aseptic meningitis[99]. In contrast, immunocompromised hosts such as transplant recipients develop severe infection with multisystem organ failure and high mortality rate. Several clusters of organ-transplant-associated LCMV infections have been reported in the USA from 2003 to 2013. Signs and symptoms suggestive of LCMV infection occurred in clusters of SOT recipients, in 2003 and 2005. Laboratory testing revealed the LCMV in all the recipients, however, the virus could not be detected in donors. Seven of eight recipients died, 9-76 d after transplantation. In the 2005 cluster, the donor reported contact with a hamster pet, infected with an LCMV strain identical to that detected in the organ recipients. No source of infection was found in the 2003 cluster[150]. In 2010-2011, four clusters of organ-transplant-associated LCMV transmissions have been reported; 11 of 14 recipients died[151]. The majority of patients with fatal donor‐derived LCMV infection showed hepatitis as a prominent feature[99]. In a recently published study, a case of LCMV infection in a renal transplant recipient that was non-organ donor-derived was described. The patient presented with meningoencephalitis acquired by the exposure to mice excreta. The clinical course was complicated by the development of hydrocephalus, requiring a ventriculoperitoneal shunt[152]. Although the risk of LCMV among organ recipients is low, clinicians should be aware of the possibility of transplant-transmitted LCMV infection.

***Toxoplasma gondii (Toxoplasmosis)***

Toxoplasmosis is a zoonotic disease caused by a protozoan *Toxoplasma gondii*. It is an obligate intracellular parasite that is widely spread all over the world. Warm-blooded vertebrates are the intermediate hosts where asexual reproduction takes place. This results in the formation of tachyzoites and bradyzoites. Tachyzoites can invade various tissues e.g. lungs, CNS and heart but also, they can cause intrauterine infection with possible transplacental transmission to the fetus. Bradyzoites form the tissue cysts in the intermediate host. Felids are the only definite hosts where sexual reproduction occurs resulting in excretion of oocysts into the environment *via* feces. Transmission to humans occurs through the ingestion of water, vegetables, or soil contaminated with oocysts or raw or undercooked meat containing tissue cysts with bradyzoites[153]. The worldwide prevalence of toxoplasmosis in the human population varies from 10 to 80%[154,155]. The course of infection is generally benign and most infected individuals remain asymptomatic or mildly symptomatic. The disease may have an acute or chronic form. The presence of bradyzoites in tissue cysts represents the latent infection which can reactivate at any age. Prenatal transplacental infection can result in intrauterine fetal growth retardation, hepatosplenomegaly, eye and/or brain damage, fetal death or premature birth. If symptomatic, postnatal toxoplasmosis can present as fever with lymphadenopathy. Chorioretinitis as a manifestation of acquired toxoplasmosis is seen less frequently. Rarely, a potentially fatal disseminated disease, myocarditis, pneumonitis, hepatitis, myositis or encephalitis can be seen in an immunocompetent patients[156]. Toxoplasmosis as an infectious complication is a well-recognized entity in SOT recipients. If it presents in the first three post-transplant mo, the graft transmission is most likely, but if it presents after this early period, most often it is the result of the latent infection reactivation or the primary infection. Clinical presentation in SOT patients is more severe as cerebral, disseminated and pulmonary toxoplasmosis is seen more often than mild forms (fever and ocular toxoplasmosis). Even more severe forms with higher mortality are seen in graft transmission[157,158]. As toxoplasmosis in SOT patients might be a fatal disease and as at the same time it is a preventable infection, clinicians have to follow the screening and chemoprophylaxis guidelines to optimize the patient’s outcome.

**CONCLUSION**

This article summarizes the most important emerging and neglected zoonotic pathogens and their clinical presentations in the transplant population.In recent decades, human activities along with climatic changes have led to the shifts in environmental conditions influencing among others, the transmission and distribution of zoonotic pathogens. As the number of zoonotic diseases is increasing, the spreading trends are likely to continue in the future. In parallel, the expanding transplant population worldwide imposes additional challenges for diagnostics and treatment of zoonotic infections. Immunosuppressed state may influence the serologic response and delay diagnosis, modify and aggravate clinical presentation and prolong treatment and recovery. Keeping that in mind is of particular importance in the context of emerging and neglected pathogens which may not be familiar to the wider community of transplant professionals in different geographical locations. The increasing trend of the pathogens transmitted and shared between animals and humans in global and especially transplant population, emphasizes the need for the multidisciplinary approach (‘One Health’) in the surveillance and control of zoonotic infections around the world.

**ACKNOWLEDGEMENTS**

This study was supported in part by the Croatian Science Foundation, project No. IP 2016-06-7456: Prevalence and molecular epidemiology of emerging and re-emerging neuroinvasive arboviral infections in Croatia; CRONEUROARBO (to TVC).

**REFERENCES**

1 **World Health Organization (WHO)**. Neglected zoonotic diseases. Available from: https://www.who.int/neglected\_diseases/diseases/zoonoses/en/

2 **Karesh WB**, Dobson A, Lloyd-Smith JO, Lubroth J, Dixon MA, Bennett M, Aldrich S, Harrington T, Formenty P, Loh EH, Machalaba CC, Thomas MJ, Heymann DL. Ecology of zoonoses: natural and unnatural histories. *Lancet* 2012; **380**: 1936-1945 [PMID: 23200502 DOI: 10.1016/S0140-6736(12)61678-X]

3 **Jánová E**. Emerging and threatening vector-borne zoonoses in the world and in Europe: a brief update. *Pathog Glob Health* 2019; **113**: 49-57 [PMID: 30916639 DOI: 10.1080/20477724.2019.1598127]

4 **Jorgensen JH,** Pfaller JA, Carroll KC, Landry ML, Funke G, Richter SS, Warnock DW. Manual of Clinical Microbiology. 11th ed. Washington: ASM Press, 2017

5 **Vilibic-Cavlek T**, Savic V, Petrovic T, Toplak I, Barbic L, Petric D, Tabain I, Hrnjakovic-Cvjetkovic I, Bogdanic M, Klobucar A, Mrzljak A, Stevanovic V, Dinjar-Kujundzic P, Radmanic L, Monaco F, Listes E, Savini G. Emerging Trends in the Epidemiology of West Nile and Usutu Virus Infections in Southern Europe. *Front Vet Sci* 2019; **6**: 437 [PMID: 31867347 DOI: 10.3389/fvets.2019.00437]

6 **Camp JV**, Nowotny N. The knowns and unknowns of West Nile virus in Europe: what did we learn from the 2018 outbreak? *Expert Rev Anti Infect Ther* 2020; **18**: 145-154 [PMID: 31914833 DOI: 10.1080/14787210.2020.1713751]

7 **European Centre for Disease Prevention and Control (ECDC)**. Historical Data by Year - West Nile Fever Seasonal Surveillance 2018. Available from: https://ecdc.europa.eu/en/west-nile-fever/surveillance-and-disease-data/historical

8 **Centers for Disease Control and Prevention (CDC)**. Zika virus. Statistics maps 2016. Available from: https://www.cdc.gov/zika/reporting/2016-case-counts.html

9 **The Lancet**. Growing concerns of hepatitis E in Europe. *Lancet* 2017; **390**: 334 [PMID: 28745588 DOI: 10.1016/S0140-6736(17)31922-0]

10 **European Association for the Study of the Liver.** EASL Clinical Practice Guidelines: Liver transplantation. *J Hepatol* 2016; **64**: 433-485 [PMID: 26597456 DOI: 10.1016/j.jhep.2015.10.006]

11 **Bodzin AS**, Baker TB. Liver Transplantation Today: Where We Are Now and Where We Are Going. *Liver Transpl* 2018; **24**: 1470-1475 [PMID: 30080954 DOI: 10.1002/lt.25320]

12 **Mansfield KL**, Johnson N, Phipps LP, Stephenson JR, Fooks AR, Solomon T. Tick-borne encephalitis virus - a review of an emerging zoonosis. *J Gen Virol* 2009; **90**: 1781-1794 [PMID: 19420159 DOI: 10.1099/vir.0.011437-0]

13 **Kerlik J**, Avdičová M, Štefkovičová M, Tarkovská V, Pántiková Valachová M, Molčányi T, Mezencev R. Slovakia reports highest occurrence of alimentary tick-borne encephalitis in Europe: Analysis of tick-borne encephalitis outbreaks in Slovakia during 2007-2016. *Travel Med Infect Dis* 2018; **26**: 37-42 [PMID: 30012472 DOI: 10.1016/j.tmaid.2018.07.001]

14 **Ruzek D**, Avšič Županc T, Borde J, Chrdle A, Eyer L, Karganova G, Kholodilov I, Knap N, Kozlovskaya L, Matveev A, Miller AD, Osolodkin DI, Överby AK, Tikunova N, Tkachev S, Zajkowska J. Tick-borne encephalitis in Europe and Russia: Review of pathogenesis, clinical features, therapy, and vaccines. *Antiviral Res* 2019; **164**: 23-51 [PMID: 30710567 DOI: 10.1016/j.antiviral.2019.01.014]

15 **Vilibic-Cavlek T**, Barbic L, Stevanovic V, Petrovic G, Mlinaric-Galinovic G. IgG Avidity: an Important Serologic Marker for the Diagnosis of Tick-Borne Encephalitis Virus Infection. *Pol J Microbiol* 2016; **65**: 119-121 [PMID: 27282004 DOI: 10.5604/17331331.1197285]

16 **Lipowski D**, Popiel M, Perlejewski K, Nakamura S, Bukowska-Osko I, Rzadkiewicz E, Dzieciatkowski T, Milecka A, Wenski W, Ciszek M, Debska-Slizien A, Ignacak E, Cortes KC, Pawelczyk A, Horban A, Radkowski M, Laskus T. A Cluster of Fatal Tick-borne Encephalitis Virus Infection in Organ Transplant Setting. *J Infect Dis* 2017; **215**: 896-901 [PMID: 28453842 DOI: 10.1093/infdis/jix040]

17 **Radolf JD**, Caimano MJ, Stevenson B, Hu LT. Of ticks, mice and men: understanding the dual-host lifestyle of Lyme disease spirochaetes. *Nat Rev Microbiol* 2012; **10**: 87-99 [PMID: 22230951 DOI: 10.1038/nrmicro2714]

18 **McGinley-Smith DE**, Tsao SS. Dermatoses from ticks. *J Am Acad Dermatol* 2003; **49**: 363-92; quiz 393-6 [PMID: 12963900 DOI: 10.1067/s0190-9622(03)01868-1]

19 **Krawczuk K**, Czupryna P, Pancewicz S, Ołdak E, Król M, Moniuszko-Malinowska A. Neuroborreliosis – clinical presentation – Current state of knowledge *Przegl Epidemiol* 2019; **73**: 321-328 [PMID: 31766829 DOI: 10.32394/pe.73.27]

20 **Maraspin V**, Cimperman J, Lotric-Furlan S, Logar M, Ruzić-Sabljić E, Strle F. Erythema migrans in solid-organ transplant recipients. *Clin Infect Dis* 2006; **42**: 1751-1754 [PMID: 16705583 DOI: 10.1086/504384]

21 **Chochon F**, Kanfer A, Rondeau E, Sraer JD. Lyme disease in a kidney transplant recipient. *Transplantation* 1994; **57**: 1687-1688 [PMID: 8009611]

22 **Ryan MF**, Thorn C. Lyme carditis in an immunocompromised patient. *Case Rep Emerg Med* 2013; **2013**: 380734 [PMID: 24083037 DOI: 10.1155/2013/380734]

23 **Dumler JS**, Choi KS, Garcia-Garcia JC, Barat NS, Scorpio DG, Garyu JW, Grab DJ, Bakken JS. Human granulocytic anaplasmosis and Anaplasma phagocytophilum. *Emerg Infect Dis* 2005; **11**: 1828-1834 [PMID: 16485466 DOI: 10.3201/eid1112.050898]

24 **European Centre for Disease Prevention and Control (ECDC)**. Human granulocytic anaplasmosis. Available from: https://www.ecdc.europa.eu/en/human-granulocytic-anaplasmosis

25 **Centers for Disease Control and Prevention (CDC).** Diagnosis and Management of Tickborne Rickettsial Diseases: Rocky Mountain Spotted Fever and Other Spotted Fever Group Rickettsioses, Ehrlichioses, and Anaplasmosis — United States A Practical Guide for Health Care and Public Health Professionals. Available from: https://www.cdc.gov/mmwr/volumes/65/rr/rr6502a1.htm

26 **Bakken JS**, Dumler JS. Human granulocytic ehrlichiosis. *Clin Infect Dis* 2000; **31**: 554-560 [PMID: 10987720 DOI: 10.1086/313948]

27 **Sanchez E**, Vannier E, Wormser GP, Hu LT. Diagnosis, Treatment, and Prevention of Lyme Disease, Human Granulocytic Anaplasmosis, and Babesiosis: A Review. *JAMA* 2016; **315**: 1767-1777 [PMID: 27115378 DOI: 10.1001/jama.2016.2884]

28 **Vannorsdall MD**, Thomas S, Smith RP, Zimmerman R, Christman R, Vella JP. Human granulocytic ehrlichiosis in a renal allograft recipient: review of the clinical spectrum of disease in solid organ transplant patients. *Transpl Infect Dis* 2002; **4**: 97-101 [PMID: 12220247 DOI: 10.1034/j.1399-3062.2002.01015.x]

29 **Adachi JA**, Grimm EM, Johnson P, Uthman M, Kaplan B, Rakita RM. Human granulocytic ehrlichiosis in a renal transplant patient: case report and review of the literature. *Transplantation* 1997; **64**: 1139-1142 [PMID: 9355830 DOI: 10.1097/00007890-199710270-00010]

30 **Antony SJ**, Dummer JS, Hunter E. Human ehrlichiosis in a liver transplant recipient. *Transplantation* 1995; **60**: 879-881 [PMID: 7482752]

31 **Assi MA**, Yao JD, Walker RC. Lyme disease followed by human granulocytic anaplasmosis in a kidney transplant recipient. *Transpl Infect Dis* 2007; **9**: 66-72 [PMID: 17313478 DOI: 10.1111/j.1399-3062.2006.00177.x]

32 **Trofe J**, Reddy KS, Stratta RJ, Flax SD, Somerville KT, Alloway RR, Egidi MF, Shokouh-Amiri MH, Gaber AO. Human granulocytic ehrlichiosis in pancreas transplant recipients. *Transpl Infect Dis* 2001; **3**: 34-39 [PMID: 11429038 DOI: 10.1034/j.1399-3062.2001.003001034.x]

33 **Khatri A**, Lloji A, Doobay R, Wang G, Knoll B, Dhand A, Nog R. Anaplasma phagocytophilum presenting with orchitis in a renal transplant recipient. *Transpl Infect Dis* 2019; **21**: e13129 [PMID: 31215144 DOI: 10.1111/tid.13129]

34 **Dana A**, Antony A, Patel MJ. Vector-borne infections in solid organ transplant recipients. *Int J Dermatol* 2012; **51**: 1-11 [PMID: 22182371 DOI: 10.1111/j.1365-4632.2011.05252.x]

35 **Dumler JS**, Madigan JE, Pusterla N, Bakken JS. Ehrlichioses in humans: epidemiology, clinical presentation, diagnosis, and treatment. *Clin Infect Dis* 2007; **45 Suppl 1**: S45-S51 [PMID: 17582569 DOI: 10.1086/518146]

36 **Tan HP**, Dumler JS, Maley WR, Klein AS, Burdick JF, Fred Poordad F, Thuluvath PJ, Markowitz JS. Human monocytic ehrlichiosis: an emerging pathogen in transplantation. *Transplantation* 2001; **71**: 1678-1680 [PMID: 11435982 DOI: 10.1097/00007890-200106150-00030]

37 **Sachdev SH**, Joshi V, Cox ER, Amoroso A, Palekar S. Severe life-threatening Ehrlichia chaffeensis infections transmitted through solid organ transplantation. *Transpl Infect Dis* 2014; **16**: 119-124 [PMID: 24330198 DOI: 10.1111/tid.12172]

38 **Regunath H**, Rojas-Moreno C, Olano JP, Hammer RD, Salzer W. Early diagnosis of Ehrlichia ewingii infection in a lung transplant recipient by peripheral blood smear. *Transpl Infect Dis* 2017; **19** [PMID: 28036138 DOI: 10.1111/tid.12652]

39 **Hamilton KS**, Standaert SM, Kinney MC. Characteristic peripheral blood findings in human ehrlichiosis. *Mod Pathol* 2004; **17**: 512-517 [PMID: 14976527 DOI: 10.1038/modpathol.3800075]

40 **Dorn HF,** Dickinson B, Agarwal A, Brayman KL. Human Ehrlichiosis after Treatment of Acute Cellular Rejection in a Kidney Transplant Patient. *Transplantation* 2012; **94**: 531 [DOI: 10.1097/00007890-201211271-01022]

41 **Sadikot R**, Shaver MJ, Reeves WB. Ehrlichia chaffeensis in a renal transplant recipient. *Am J Nephrol* 1999; **19**: 674-676 [PMID: 10592362 DOI: 10.1159/000013540]

42 **Lawrence KL**, Morrell MR, Storch GA, Hachem RR, Trulock EP. Clinical outcomes of solid organ transplant recipients with ehrlichiosis. *Transpl Infect Dis* 2009; **11**: 203-210 [PMID: 19228344 DOI: 10.1111/j.1399-3062.2009.00373.x]

43 **Thomas LD**, Hongo I, Bloch KC, Tang YW, Dummer S. Human ehrlichiosis in transplant recipients. *Am J Transplant* 2007; **7**: 1641-1647 [PMID: 17511689 DOI: 10.1111/j.1600-6143.2007.01821.x]

44 **Cotant C**, Okulicz JF, Brezina B, Riley DJ, Conger NG. Human monocytic ehrlichiosis in a renal transplant patient. *Scand J Infect Dis* 2006; **38**: 699-702 [PMID: 16857619 DOI: 10.1080/00365540500444694]

45 **Liddell AM**, Sumner JW, Paddock CD, Rikihisa Y, Unver A, Buller RS, Storch GA. Reinfection with Ehrlichia chaffeensis in a liver transplant recipient. *Clin Infect Dis* 2002; **34**: 1644-1647 [PMID: 12032902 DOI: 10.1086/340523]

46 **Safdar N**, Love RB, Maki DG. Severe Ehrlichia chaffeensis infection in a lung transplant recipient: a review of ehrlichiosis in the immunocompromised patient. *Emerg Infect Dis* 2002; **8**: 320-323 [PMID: 11927032 DOI: 10.3201/eid0803.010249]

47 **Parola P**, Paddock CD, Raoult D. Tick-borne rickettsioses around the world: emerging diseases challenging old concepts. *Clin Microbiol Rev* 2005; **18**: 719-756 [PMID: 16223955 DOI: 10.1128/CMR.18.4.719-756.2005]

48 **European Centre for Disease Prevention and Control**. Epidemiological situation of rickettsioses in EU/EFTA countries. [accessed December 2019]. Available from: https://www.ecdc.europa.eu/en/publications-data/epidemiological-situation-rickettsioses-euefta-countries

49 **Adem PV**. Emerging and re-emerging rickettsial infections. *Semin Diagn Pathol* 2019; **36**: 146-151 [PMID: 31101391 DOI: 10.1053/j.semdp.2019.04.005]

50 **Rallis TM**, Kriesel JD, Dumler JS, Wagoner LE, Wright ED, Spruance SL. Rocky Mountain spotted fever following cardiac transplantation. *West J Med* 1993; **158**: 625-628 [PMID: 8337866]

51 **Schmulewitz L**, Moumile K, Patey-Mariaud de Serre N, Poirée S, Gouin E, Mechaï F, Cocard V, Mamzer-Bruneel MF, Abachin E, Berche P, Lortholary O, Lecuit M. Splenic rupture and malignant Mediterranean spotted fever. *Emerg Infect Dis* 2008; **14**: 995-997 [PMID: 18507929 DOI: 10.3201/eid1406.071295]

52 **Chakraborty S**, Sarma N. Scrub Typhus: An Emerging Threat. *Indian J Dermatol* 2017; **62**: 478-485 [PMID: 28979009 DOI: 10.4103/ijd.IJD\_388\_17]

53 **Dhanapriya J**, Dineshkumar T, Sakthirajan R, Murugan S, Jayaprakash V, Balasubramaniyan T, Gopalakrishnan N. Scrub typhus meningitis in a renal transplant recipient. *Indian J Nephrol* 2017; **27**: 151-153 [PMID: 28356672 DOI: 10.4103/0971-4065.181883]

54 **Peter JV**, Sudarsan TI, Prakash JA, Varghese GM. Severe scrub typhus infection: Clinical features, diagnostic challenges and management. *World J Crit Care Med* 2015; **4**: 244-250 [PMID: 26261776 DOI: 10.5492/wjccm.v4.i3.244]

55 **Luce-Fedrow A**, Lehman ML, Kelly DJ, Mullins K, Maina AN, Stewart RL, Ge H, John HS, Jiang J, Richards AL. A Review of Scrub Typhus (Orientia tsutsugamushi and Related Organisms): Then, Now, and Tomorrow. *Trop Med Infect Dis* 2018; **3** [PMID: 30274407 DOI: 10.3390/tropicalmed3010008]

56 **Balenghien T**, Cardinale E, Chevalier V, Elissa N, Failloux AB, Jean Jose Nipomichene TN, Nicolas G, Rakotoharinome VM, Roger M, Zumbo B. Towards a better understanding of Rift Valley fever epidemiology in the south-west of the Indian Ocean. *Vet Res* 2013; **44**: 78 [PMID: 24016237 DOI: 10.1186/1297-9716-44-78]

57 **Linthicum KJ**, Britch SC, Anyamba A. Rift Valley Fever: An Emerging Mosquito-Borne Disease. *Annu Rev Entomol* 2016; **61**: 395-415 [PMID: 26982443 DOI: 10.1146/annurev-ento-010715-023819]

58 **Clark MHA**, Warimwe GM, Di Nardo A, Lyons NA, Gubbins S. Systematic literature review of Rift Valley fever virus seroprevalence in livestock, wildlife and humans in Africa from 1968 to 2016. *PLoS Negl Trop Dis* 2018; **12**: e0006627 [PMID: 30036382 DOI: 10.1371/journal.pntd.0006627]

59 **McMillen CM**, Hartman AL. Rift Valley fever in animals and humans: Current perspectives. *Antiviral Res* 2018; **156**: 29-37 [PMID: 29857007 DOI: 10.1016/j.antiviral.2018.05.009]

60 **Mansfield KL**, Banyard AC, McElhinney L, Johnson N, Horton DL, Hernández-Triana LM, Fooks AR. Rift Valley fever virus: A review of diagnosis and vaccination, and implications for emergence in Europe. *Vaccine* 2015; **33**: 5520-5531 [PMID: 26296499 DOI: 10.1016/j.vaccine.2015.08.020]

61 **Haneche F**, Leparc-Goffart I, Simon F, Hentzien M, Martinez-Pourcher V, Caumes E, Maquart M. Rift Valley fever in kidney transplant recipient returning from Mali with viral RNA detected in semen up to four months from symptom onset, France, autumn 2015. *Euro Surveill* 2016; **21** [PMID: 27172608 DOI: 10.2807/1560-7917.ES.2016.21.18.30222]

62 **Diaz A**, Coffey LL, Burkett-Cadena N, Day JF. Reemergence of St. Louis Encephalitis Virus in the Americas. *Emerg Infect Dis* 2018; **24** [PMID: 30457961 DOI: 10.3201/eid2412.180372]

63 **Simon LV,** Graham C. Louis Encephalitis. Treasure Island, FL: StatPearls Publishing, 2019

64 **Oyer RJ**, David Beckham J, Tyler KL. West Nile and St. Louis encephalitis viruses. *Handb Clin Neurol* 2014; **123**: 433-447 [PMID: 25015498 DOI: 10.1016/B978-0-444-53488-0.00020-1]

65 **Hartmann CA**, Vikram HR, Seville MT, Orenstein R, Kusne S, Blair JE, Grys TE, Patron RL. Neuroinvasive St. Louis Encephalitis Virus Infection in Solid Organ Transplant Recipients. *Am J Transplant* 2017; **17**: 2200-2206 [PMID: 28452107 DOI: 10.1111/ajt.14336]

66 **Duffy MR**, Chen TH, Hancock WT, Powers AM, Kool JL, Lanciotti RS, Pretrick M, Marfel M, Holzbauer S, Dubray C, Guillaumot L, Griggs A, Bel M, Lambert AJ, Laven J, Kosoy O, Panella A, Biggerstaff BJ, Fischer M, Hayes EB. Zika virus outbreak on Yap Island, Federated States of Micronesia. *N Engl J Med* 2009; **360**: 2536-2543 [PMID: 19516034 DOI: 10.1056/NEJMoa0805715]

67 **Noorbakhsh F**, Abdolmohammadi K, Fatahi Y, Dalili H, Rasoolinejad M, Rezaei F, Salehi-Vaziri M, Shafiei-Jandaghi NZ, Gooshki ES, Zaim M, Nicknam MH. Zika Virus Infection, Basic and Clinical Aspects: A Review Article. *Iran J Public Health* 2019; **48**: 20-31 [PMID: 30847308]

68 **Rodriguez-Morales AJ**, Bandeira AC, Franco-Paredes C. The expanding spectrum of modes of transmission of Zika virus: a global concern. *Ann Clin Microbiol Antimicrob* 2016; **15**: 13 [PMID: 26939897 DOI: 10.1186/s12941-016-0128-2]

69 **European Centre for Disease Prevention and Control (ECDC)**. Laboratory tests for Zika virus diagnostic. Available from: https://www.ecdc.europa.eu/en/publications-data/laboratory-tests-zika-virus-diagnostic

70 **Wright JK**, Castellani L, Lecce C, Khatib A, Bonta M, Boggild AK. Zika Virus-Associated Aseptic Meningitis and Guillain-Barre Syndrome in a Traveler Returning from Latin America: a Case Report and Mini-Review. *Curr Infect Dis Rep* 2019; **21**: 3 [PMID: 30767073 DOI: 10.1007/s11908-019-0661-1]

71 **Nogueira ML**, Estofolete CF, Terzian AC, Mascarin do Vale EP, da Silva RC, da Silva RF, Ramalho HJ, Fernandes Charpiot IM, Vasilakis N, Abbud-Filho M. Zika Virus Infection and Solid Organ Transplantation: A New Challenge. *Am J Transplant* 2017; **17**: 791-795 [PMID: 27629942 DOI: 10.1111/ajt.14047]

72 **Vairo F**, Haider N, Kock R, Ntoumi F, Ippolito G, Zumla A. Chikungunya: Epidemiology, Pathogenesis, Clinical Features, Management, and Prevention. *Infect Dis Clin North Am* 2019; **33**: 1003-1025 [PMID: 31668189 DOI: 10.1016/j.idc.2019.08.006]

73 **Ganesan VK**, Duan B, Reid SP. Chikungunya Virus: Pathophysiology, Mechanism, and Modeling. *Viruses* 2017; **9** [PMID: 29194359 DOI: 10.3390/v9120368]

74 **Economopoulou A**, Dominguez M, Helynck B, Sissoko D, Wichmann O, Quenel P, Germonneau P, Quatresous I. Atypical Chikungunya virus infections: clinical manifestations, mortality and risk factors for severe disease during the 2005-2006 outbreak on Réunion. *Epidemiol Infect* 2009; **137**: 534-541 [PMID: 18694529 DOI: 10.1017/S0950268808001167]

75 **Bonifay T**, Prince C, Neyra C, Demar M, Rousset D, Kallel H, Nacher M, Djossou F, Epelboin L; Char Chik Working group. Atypical and severe manifestations of chikungunya virus infection in French Guiana: A hospital-based study. *PLoS One* 2018; **13**: e0207406 [PMID: 30521555 DOI: 10.1371/journal.pone.0207406]

76 **Dalla Gasperina D**, Balsamo ML, Garavaglia SD, Rovida F, Baldanti F, Grossi PA. Chikungunya infection in a human immunodeficiency virus-infected kidney transplant recipient returning to Italy from the Dominican Republic. *Transpl Infect Dis* 2015; **17**: 876-879 [PMID: 26771689 DOI: 10.1111/tid.12453]

77 **Pierrotti LC**, Lopes MIBF, Nascimento APD, Caiaffa-Filho H, Lemos FBC, Reusing JO Jr, Sejas ONE, David-Neto E, Azevedo LS. Chikungunya in kidney transplant recipients: A series of cases. *Int J Infect Dis* 2017; **64**: 96-99 [PMID: 28941631 DOI: 10.1016/j.ijid.2017.09.009]

78 **Rosso F**, Rodríguez S, Cedano JA, Mora BL, Moncada PA, Velez JD. Chikungunya in solid organ transplant recipients, a case series and literature review. *Transpl Infect Dis* 2018; **20**: e12978 [PMID: 30120808 DOI: 10.1111/tid.12978]

79 **Foresto RD**, Santos DWCL, Hazin MAA, Leyton ATZ, Tenório NC, Viana LA, Cristelli MP, Silva Júnior HT, Pestana JOM. Chikungunya in a kidney transplant recipient: a case report. *J Bras Nefrol* 2019; **41**: 575-579 [PMID: 31419273 DOI: 10.1590/2175-8239-JBN-2018-0196]

80 **Girão ES**, Rodrigues Dos Santos BG, do Amaral ES, Costa PEG, Pereira KB, de Araujo Filho AH, Hyppolito EB, Mota MU, Marques LCBF, Costa de Oliveira CM, da Silva SL, Garcia JHP, Fernandes PFCBC. Chikungunya Infection in Solid Organ Transplant Recipients. *Transplant Proc* 2017; **49**: 2076-2081 [PMID: 29149964 DOI: 10.1016/j.transproceed.2017.07.004]

81 **Gupta RK**, Gupta G, Chorasiya VK, Bag P, Shandil R, Bhatia V, Wadhawan M, Vij V, Kumar A. Dengue Virus Transmission from Living Donor to Recipient in Liver Transplantation: A Case Report. *J Clin Exp Hepatol* 2016; **6**: 59-61 [PMID: 27194898 DOI: 10.1016/j.jceh.2016.01.005]

82 **Kalayanarooj S**. Clinical Manifestations and Management of Dengue/DHF/DSS. *Trop Med Health* 2011; **39**: 83-87 [PMID: 22500140 DOI: 10.2149/tmh.2011-S10]

83 **Muller DA**, Depelsenaire AC, Young PR. Clinical and Laboratory Diagnosis of Dengue Virus Infection. *J Infect Dis* 2017; **215**: S89-S95 [PMID: 28403441 DOI: 10.1093/infdis/jiw649]

84 **Nasim A**, Anis S, Baqi S, Akhtar SF, Baig-Ansari N. Clinical presentation and outcome of dengue viral infection in live-related renal transplant recipients in Karachi, Pakistan. *Transpl Infect Dis* 2013; **15**: 516-525 [PMID: 23890225 DOI: 10.1111/tid.12114]

85 **Maia SH**, Brasil IR, Esmeraldo Rde M, Ponte CN, Costa RC, Lira RA. Severe dengue in the early postoperative period after kidney transplantation: two case reports from Hospital Geral de Fortaleza. *Rev Soc Bras Med Trop* 2015; **48**: 783-785 [PMID: 26676509 DOI: 10.1590/0037-8682-0205-2015]

86 **Weerakkody RM,** Palangasinghe DR, Wijewickrama ES. Dengue fever in a kidney transplant recipient with complicated clinical course: a case report. *J Med Case Rep* 2018; **12**: 260 [PMID: 30170627 DOI: 10.1186/s13256-018-1790-0]

87 **Pinsai S**, Kiertiburanakul S, Watcharananan SP, Kantachuvessiri S, Boongird S, Bruminhent J. Epidemiology and outcomes of dengue in kidney transplant recipients: A 20-year retrospective analysis and comparative literature review. *Clin Transplant* 2019; **33**: e13458 [PMID: 30506903 DOI: 10.1111/ctr.13458]

88 **Rosso F**, Sanz AM, Parra-Lara LG, Moncada PA, Vélez JD, Caicedo LA. Dengue Virus Infection in Solid Organ Transplant Recipients: A Case Series and Literature Review. *Am J Trop Med Hyg* 2019; **101**: 1226-1231 [PMID: 31628736 DOI: 10.4269/ajtmh.19-0414]

89 **Kenwar D,** Kallepalli V, Sharma A, Singh S, Singh N, Kapoor K, Chamb S. Dengue in the Renal Transplant Population - A Single Center Experience. *Transplantation* 2018; **102**: 663 [DOI: 10.1097/01.tp.0000543596.39922.78]

90 **Shaji Mathew J**, Menon V, Surendran S. Dengue virus transmission from live donor liver graft: Comments and clarifications. *Am J Transplant* 2019; **19**: 2140 [PMID: 30768850 DOI: 10.1111/ajt.15314]

91 **Rosso F**, Pineda JC, Sanz AM, Cedano JA, Caicedo LA. Transmission of dengue virus from deceased donors to solid organ transplant recipients: case report and literature review. *Braz J Infect Dis* 2018; **22**: 63-69 [PMID: 29353669 DOI: 10.1016/j.bjid.2018.01.001]

92 **Cedano JA**, Mora BL, Parra-Lara LG, Manzano-Nuñez R, Rosso F. A scoping review of transmission of dengue virus from donors to recipients after solid organ transplantation. *Trans R Soc Trop Med Hyg* 2019; **113**: 431-436 [PMID: 31034049 DOI: 10.1093/trstmh/trz024]

93 **Janani MK**, Durgadevi P, Padmapriya J, Malathi J, Kulandai LT, Rao Madhavan HN. First Report on Detection of Dengue Virus in the Donor Cornea. *Cornea* 2018; **37**: 1586-1589 [PMID: 30272614 DOI: 10.1097/ICO.0000000000001706]

94 **Zannoli S**, Sambri V. West Nile Virus and Usutu Virus Co-Circulation in Europe: Epidemiology and Implications. *Microorganisms* 2019; **7** [PMID: 31248051 DOI: 10.3390/microorganisms7070184]

95 **Sejvar JJ**. Clinical manifestations and outcomes of West Nile virus infection. *Viruses* 2014; **6**: 606-623 [PMID: 24509812 DOI: 10.3390/v6020606]

96 **Di Gennaro A**, Lorusso A, Casaccia C, Conte A, Monaco F, Savini G. Serum neutralization assay can efficiently replace plaque reduction neutralization test for detection and quantitation of West Nile virus antibodies in human and animal serum samples. *Clin Vaccine Immunol* 2014; **21**: 1460-1462 [PMID: 25100824 DOI: 10.1128/CVI.00426-14]

97 **Vilibic-Cavlek T**, Kristofic B, Savic V, Kolaric B, Barbic L, Tabain I, Peric L, Sabadi D, Miklausic B, Potocnik-Hunjadi T, Zember S, Stevanovic V, Listes E, Savini G. Diagnostic significance of immunoglobulin G avidity in symptomatic and asymptomatic West Nile virus infection. *Rev Soc Bras Med Trop* 2018; **51**: 591-595 [PMID: 30304263 DOI: 10.1590/0037-8682-0482-2017]

98 **Zanoni F,** Alfieri C, Moroni G, Passerini P, Regalia A, Meneghini M, Messa P. Delayed Diagnosis of West Nile Virus Infection in a Kidney Transplant Patient Due to Inaccuracies in Commonly Available Diagnostic Tests. *Experimental and Clinical Transplantation* 2018; **1** [DOI: 10.6002/ect.2018.0107]

99 **Anesi JA**, Silveira FP; AST Infectious Diseases Community of Practice. Arenaviruses and West Nile Virus in solid organ transplant recipients: Guidelines from the American Society of Transplantation Infectious Diseases Community of Practice. *Clin Transplant* 2019; **33**: e13576 [PMID: 31022306 DOI: 10.1111/ctr.13576]

100 **Iwamoto M**, Jernigan DB, Guasch A, Trepka MJ, Blackmore CG, Hellinger WC, Pham SM, Zaki S, Lanciotti RS, Lance-Parker SE, DiazGranados CA, Winquist AG, Perlino CA, Wiersma S, Hillyer KL, Goodman JL, Marfin AA, Chamberland ME, Petersen LR; West Nile Virus in Transplant Recipients Investigation Team. Transmission of West Nile virus from an organ donor to four transplant recipients. *N Engl J Med* 2003; **348**: 2196-2203 [PMID: 12773646 DOI: 10.1056/NEJMoa022987]

101 **Hardinger KL**, Miller B, Storch GA, Desai NM, Brennan DC. West Nile virus-associated meningoencephalitis in two chronically immunosuppressed renal transplant recipients. *Am J Transplant* 2003; **3**: 1312-1315 [PMID: 14510707 DOI: 10.1046/j.1600-6143.2003.00223.x]

102 **Kleinschmidt-DeMasters BK**, Marder BA, Levi ME, Laird SP, McNutt JT, Escott EJ, Everson GT, Tyler KL. Naturally acquired West Nile virus encephalomyelitis in transplant recipients: clinical, laboratory, diagnostic, and neuropathological features. *Arch Neurol* 2004; **61**: 1210-1220 [PMID: 15313837 DOI: 10.1001/archneur.61.8.1210]

103 **DeSalvo D**, Roy-Chaudhury P, Peddi R, Merchen T, Konijetti K, Gupta M, Boardman R, Rogers C, Buell J, Hanaway M, Broderick J, Smith R, Woodle ES. West Nile virus encephalitis in organ transplant recipients: another high-risk group for meningoencephalitis and death. *Transplantation* 2004; **77**: 466-469 [PMID: 14966429 DOI: 10.1097/01.TP.0000101434.98873.CB]

104 **Ravindra KV**, Freifeld AG, Kalil AC, Mercer DF, Grant WJ, Botha JF, Wrenshall LE, Stevens RB. West Nile virus-associated encephalitis in recipients of renal and pancreas transplants: case series and literature review. *Clin Infect Dis* 2004; **38**: 1257-1260 [PMID: 15127337 DOI: 10.1086/383325]

105 **Bragin-Sánchez D**, Chang PP. West Nile virus encephalitis infection in a heart transplant recipient: a case report. *J Heart Lung Transplant* 2005; **24**: 621-623 [PMID: 15896763 DOI: 10.1016/j.healun.2004.01.005]

106 **Jain N**, Fisk D, Sotir M, Kehl KS. West Nile encephalitis, status epilepticus and West Nile pneumonia in a renal transplant patient. *Transpl Int* 2007; **20**: 800-803 [PMID: 17630998 DOI: 10.1111/j.1432-2277.2007.00514.x]

107 **Inojosa WO**, Scotton PG, Fuser R, Giobbia M, Paolin A, Maresca MC, Brunello A, Nascimben E, Sorbara C, Rigoli R, Berti R, Gajo GB, Giometto B. West Nile virus transmission through organ transplantation in north-eastern Italy: a case report and implications for pre-procurement screening. *Infection* 2012; **40**: 557-562 [PMID: 22544764 DOI: 10.1007/s15010-012-0263-4]

108 **Winston DJ**, Vikram HR, Rabe IB, Dhillon G, Mulligan D, Hong JC, Busuttil RW, Nowicki MJ, Mone T, Civen R, Tecle SA, Trivedi KK, Hocevar SN; West Nile Virus Transplant-Associated Transmission Investigation Team. Donor-derived West Nile virus infection in solid organ transplant recipients: report of four additional cases and review of clinical, diagnostic, and therapeutic features. *Transplantation* 2014; **97**: 881-889 [PMID: 24827763 DOI: 10.1097/TP.0000000000000024]

109 **Dong E**, Morris K, Sodhi G, Chang D, Czer L, Chung J, Zabner R, Raastad K, Klapper E, Kobashigawa J, Nurok M. Neuroinvasive West Nile Virus Post-Heart Transplantation: A Case Report. *Transplant Proc* 2018; **50**: 4057-4061 [PMID: 30577314 DOI: 10.1016/j.transproceed.2018.08.036]

110 **Rabe IB**, Schwartz BS, Farnon EC, Josephson SA, Webber AB, Roberts JP, de Mattos AM, Gallay BJ, van Slyck S, Messenger SL, Yen CJ, Bloch EM, Drew CP, Fischer M, Glaser CA; WNV Transplant Investigation Team. Fatal transplant-associated west nile virus encephalitis and public health investigation-california, 2010. *Transplantation* 2013; **96**: 463-468 [PMID: 23823653 DOI: 10.1097/TP.0b013e31829b4142]

111 **Francisco AM**, Glaser C, Frykman E, Cole B, Cheung M, Meyers H, Ginsberg M, Deckert A, Jean C, Jinadu BA. 2004 California pediatric West Nile virus case series. *Pediatr Infect Dis J* 2006; **25**: 81-84 [PMID: 16395112 DOI: 10.1097/01.inf.0000195612.04911.b2]

112 **Lambert SL**, Aviles D, Vehaskari VM, Ashoor IF. Severe West Nile virus meningoencephalitis in a pediatric renal transplant recipient: successful recovery and long-term neuropsychological outcome. *Pediatr Transplant* 2016; **20**: 836-839 [PMID: 27470315 DOI: 10.1111/petr.12768]

113 **Weissenböck H**, Bakonyi T, Rossi G, Mani P, Nowotny N. Usutu virus, Italy, 1996. *Emerg Infect Dis* 2013; **19**: 274-277 [PMID: 23347844 DOI: 10.3201/eid1902.121191]

114 **Vilibic-Cavlek T**, Kaic B, Barbic L, Pem-Novosel I, Slavic-Vrzic V, Lesnikar V, Kurecic-Filipovic S, Babic-Erceg A, Listes E, Stevanovic V, Gjenero-Margan I, Savini G. First evidence of simultaneous occurrence of West Nile virus and Usutu virus neuroinvasive disease in humans in Croatia during the 2013 outbreak. *Infection* 2014; **42**: 689-695 [PMID: 24793998 DOI: 10.1007/s15010-014-0625-1]

115 **Santini M**, Vilibic-Cavlek T, Barsic B, Barbic L, Savic V, Stevanovic V, Listes E, Di Gennaro A, Savini G. First cases of human Usutu virus neuroinvasive infection in Croatia, August-September 2013: clinical and laboratory features. *J Neurovirol* 2015; **21**: 92-97 [PMID: 25361698 DOI: 10.1007/s13365-014-0300-4]

116 **Vilibic-Cavlek T**, Savic V, Sabadi D, Peric L, Barbic L, Klobucar A, Miklausic B, Tabain I, Santini M, Vucelja M, Dvorski E, Butigan T, Kolaric-Sviben G, Potocnik-Hunjadi T, Balenovic M, Bogdanic M, Andric Z, Stevanovic V, Capak K, Balicevic M, Listes E, Savini G. Prevalence and molecular epidemiology of West Nile and Usutu virus infections in Croatia in the 'One health' context, 2018. *Transbound Emerg Dis* 2019; **66**: 1946-1957 [PMID: 31067011 DOI: 10.1111/tbed.13225]

117 **Pacenti M**, Sinigaglia A, Martello T, De Rui ME, Franchin E, Pagni S, Peta E, Riccetti S, Milani A, Montarsi F, Capelli G, Doroldi CG, Bigolin F, Santelli L, Nardetto L, Zoccarato M, Barzon L. Clinical and virological findings in patients with Usutu virus infection, northern Italy, 2018. *Euro Surveill* 2019; **24** [PMID: 31771697 DOI: 10.2807/1560-7917.ES.2019.24.47.1900180]

118 **Pecorari M**, Longo G, Gennari W, Grottola A, Sabbatini A, Tagliazucchi S, Savini G, Monaco F, Simone M, Lelli R, Rumpianesi F. First human case of Usutu virus neuroinvasive infection, Italy, August-September 2009. *Euro Surveill* 2009; **14** [PMID: 20070936]

119 **Nagy A**, Mezei E, Nagy O, Bakonyi T, Csonka N, Kaposi M, Koroknai A, Szomor K, Rigó Z, Molnár Z, Dánielisz Á, Takács M. Extraordinary increase in West Nile virus cases and first confirmed human Usutu virus infection in Hungary, 2018. *Euro Surveill* 2019; **24** [PMID: 31311619 DOI: 10.2807/1560-7917.ES.2019.24.28.1900038]

120 **Simonin Y**, Sillam O, Carles MJ, Gutierrez S, Gil P, Constant O, Martin MF, Girard G, Van de Perre P, Salinas S, Leparc-Goffart I, Foulongne V. Human Usutu Virus Infection with Atypical Neurologic Presentation, Montpellier, France, 2016. *Emerg Infect Dis* 2018; **24**: 875-878 [PMID: 29664365 DOI: 10.3201/eid2405.171122]

121 **Cavrini F**, Gaibani P, Longo G, Pierro AM, Rossini G, Bonilauri P, Gerunda GE, Di Benedetto F, Pasetto A, Girardis M, Dottori M, Landini MP, Sambri V. Usutu virus infection in a patient who underwent orthotropic liver transplantation, Italy, August-September 2009. *Euro Surveill* 2009; **14** [PMID: 20070935]

122 **Morens DM**, Folkers GK, Fauci AS. Eastern Equine Encephalitis Virus - Another Emergent Arbovirus in the United States. *N Engl J Med* 2019; **381**: 1989-1992 [PMID: 31747726 DOI: 10.1056/NEJMp1914328]

123 **Lindsey NP**, Staples JE, Fischer M. Eastern Equine Encephalitis Virus in the United States, 2003-2016. *Am J Trop Med Hyg* 2018; **98**: 1472-1477 [PMID: 29557336 DOI: 10.4269/ajtmh.17-0927]

124 **Pouch SM**, Katugaha SB, Shieh WJ, Annambhotla P, Walker WL, Basavaraju SV, Jones J, Huynh T, Reagan-Steiner S, Bhatnagar J, Grimm K, Stramer SL, Gabel J, Lyon GM, Mehta AK, Kandiah P, Neujahr DC, Javidfar J, Subramanian RM, Parekh SM, Shah P, Cooper L, Psotka MA, Radcliffe R, Williams C, Zaki SR, Staples JE, Fischer M, Panella AJ, Lanciotti RS, Laven JJ, Kosoy O, Rabe IB, Gould CV; Eastern Equine Encephalitis Virus Transplant Transmission Investigation Team. Transmission of Eastern Equine Encephalitis Virus From an Organ Donor to 3 Transplant Recipients. *Clin Infect Dis* 2019; **69**: 450-458 [PMID: 30371754 DOI: 10.1093/cid/ciy923]

125 **Steverding D**. The history of leishmaniasis. *Parasit Vectors* 2017; **10**: 82 [PMID: 28202044 DOI: 10.1186/s13071-017-2028-5]

126 **Antinori S**, Schifanella L, Corbellino M. Leishmaniasis: new insights from an old and neglected disease. *Eur J Clin Microbiol Infect Dis* 2012; **31**: 109-118 [PMID: 21533874 DOI: 10.1007/s10096-011-1276-0]

127 **van Griensven J**, Diro E. Visceral Leishmaniasis: Recent Advances in Diagnostics and Treatment Regimens. *Infect Dis Clin North Am* 2019; **33**: 79-99 [PMID: 30712769 DOI: 10.1016/j.idc.2018.10.005]

128 **Antinori S**, Cascio A, Parravicini C, Bianchi R, Corbellino M. Leishmaniasis among organ transplant recipients. *Lancet Infect Dis* 2008; **8**: 191-199 [PMID: 18291340 DOI: 10.1016/S1473-3099(08)70043-4]

129 **Clemente WT**, Mourão PHO, Lopez-Medrano F, Schwartz BS, García-Donoso C, Torre-Cisneros J. Visceral and Cutaneous Leishmaniasis Recommendations for Solid Organ Transplant Recipients and Donors. *Transplantation* 2018; **102**: S8-S15 [PMID: 29381573 DOI: 10.1097/TP.0000000000002018]

130 **Clemente W**, Vidal E, Girão E, Ramos AS, Govedic F, Merino E, Muñoz P, Sabé N, Cervera C, Cota GF, Cordero E, Mena A, Montejo M, López-Medrano F, Aguado JM, Fernandes P, Valerio M, Carratalá J, Moreno A, Oliveira J, Mourão PH, Torre-Cisneros J. Risk factors, clinical features and outcomes of visceral leishmaniasis in solid-organ transplant recipients: a retrospective multicenter case-control study. *Clin Microbiol Infect* 2015; **21**: 89-95 [PMID: 25636932 DOI: 10.1016/j.cmi.2014.09.002]

131 **European Association for the Study of the Liver.** EASL Clinical Practice Guidelines on hepatitis E virus infection. *J Hepatol* 2018; **68**: 1256-1271 [PMID: 29609832 DOI: 10.1016/j.jhep.2018.03.005]

132 **Blasco-Perrin H**, Madden RG, Stanley A, Crossan C, Hunter JG, Vine L, Lane K, Devooght-Johnson N, Mclaughlin C, Petrik J, Stableforth B, Hussaini H, Phillips M, Mansuy JM, Forrest E, Izopet J, Blatchford O, Scobie L, Peron JM, Dalton HR. Hepatitis E virus in patients with decompensated chronic liver disease: a prospective UK/French study. *Aliment Pharmacol Ther* 2015; **42**: 574-581 [PMID: 26174470 DOI: 10.1111/apt.13309]

133 **Kamar N**, Selves J, Mansuy JM, Ouezzani L, Péron JM, Guitard J, Cointault O, Esposito L, Abravanel F, Danjoux M, Durand D, Vinel JP, Izopet J, Rostaing L. Hepatitis E virus and chronic hepatitis in organ-transplant recipients. *N Engl J Med* 2008; **358**: 811-817 [PMID: 18287603 DOI: 10.1056/NEJMoa0706992]

134 **Kamar N**, Garrouste C, Haagsma EB, Garrigue V, Pischke S, Chauvet C, Dumortier J, Cannesson A, Cassuto-Viguier E, Thervet E, Conti F, Lebray P, Dalton HR, Santella R, Kanaan N, Essig M, Mousson C, Radenne S, Roque-Afonso AM, Izopet J, Rostaing L. Factors associated with chronic hepatitis in patients with hepatitis E virus infection who have received solid organ transplants. *Gastroenterology* 2011; **140**: 1481-1489 [PMID: 21354150 DOI: 10.1053/j.gastro.2011.02.050]

135 **Woolson KL**, Forbes A, Vine L, Beynon L, McElhinney L, Panayi V, Hunter JG, Madden RG, Glasgow T, Kotecha A, Dalton HC, Mihailescu L, Warshow U, Hussaini HS, Palmer J, Mclean BN, Haywood B, Bendall RP, Dalton HR. Extra-hepatic manifestations of autochthonous hepatitis E infection. *Aliment Pharmacol Ther* 2014; **40**: 1282-1291 [PMID: 25303615 DOI: 10.1111/apt.12986]

136 **Kamar N**, Weclawiak H, Guilbeau-Frugier C, Legrand-Abravanel F, Cointault O, Ribes D, Esposito L, Cardeau-Desangles I, Guitard J, Sallusto F, Muscari F, Peron JM, Alric L, Izopet J, Rostaing L. Hepatitis E virus and the kidney in solid-organ transplant patients. *Transplantation* 2012; **93**: 617-623 [PMID: 22298032 DOI: 10.1097/TP.0b013e318245f14c]

137 **Kamar N,** Abravanel F, Behrendt P, Hofmann J, Pageaux GP, Barbet C, Moal V, Couzi L, Horvatits T, De Man RA, Cassuto E, Elsharkawy AM, Riezebos-Brilman A, Scemla A, Hillaire S, Donnelly MC, Radenne S, Sayegh J, Garrouste C, Dumortier J, Glowaki F, Matignon M, Coilly A, Figueres L, Mousson C, Minello A, Dharancy S, Rerolle JP, Lebray P, Etienne I, Perrin P, Choi M, Marion O, Izopet J, Hepatitis E Virus Ribavirin Study Group. Ribavirin for Hepatitis E Virus Infection After Organ Transplantation: A Large European Retrospective Multicenter Study. *Clinical Infectious Diseases* 2019 [DOI: 10.1093/cid/ciz953]

138 **World Health Organisation (WHO)**. Rabies Bulletin - Europe. Available from: https://www.who-rabies-bulletin.org/site-page/epidemiology-rabies

139 **Houff SA**, Burton RC, Wilson RW, Henson TE, London WT, Baer GM, Anderson LJ, Winkler WG, Madden DL, Sever JL. Human-to-human transmission of rabies virus by corneal transplant. *N Engl J Med* 1979; **300**: 603-604 [PMID: 368632 DOI: 10.1056/NEJM197903153001105]

140 **Javadi MA**, Fayaz A, Mirdehghan SA, Ainollahi B. Transmission of rabies by corneal graft. *Cornea* 1996; **15**: 431-433 [PMID: 8776570 DOI: 10.1097/00003226-199607000-00014]

141 **Maier T**, Schwarting A, Mauer D, Ross RS, Martens A, Kliem V, Wahl J, Panning M, Baumgarte S, Müller T, Pfefferle S, Ebel H, Schmidt J, Tenner-Racz K, Racz P, Schmid M, Strüber M, Wolters B, Gotthardt D, Bitz F, Frisch L, Pfeiffer N, Fickenscher H, Sauer P, Rupprecht CE, Roggendorf M, Haverich A, Galle P, Hoyer J, Drosten C. Management and outcomes after multiple corneal and solid organ transplantations from a donor infected with rabies virus. *Clin Infect Dis* 2010; **50**: 1112-1119 [PMID: 20205588 DOI: 10.1086/651267]

142 **Vetter JM**, Frisch L, Drosten C, Ross RS, Roggendorf M, Wolters B, Müller T, Dick HB, Pfeiffer N. Survival after transplantation of corneas from a rabies-infected donor. *Cornea* 2011; **30**: 241-244 [PMID: 20847660 DOI: 10.1097/ICO.0b013e3181e4572a]

143 **Srinivasan A**, Burton EC, Kuehnert MJ, Rupprecht C, Sutker WL, Ksiazek TG, Paddock CD, Guarner J, Shieh WJ, Goldsmith C, Hanlon CA, Zoretic J, Fischbach B, Niezgoda M, El-Feky WH, Orciari L, Sanchez EQ, Likos A, Klintmalm GB, Cardo D, LeDuc J, Chamberland ME, Jernigan DB, Zaki SR; Rabies in Transplant Recipients Investigation Team. Transmission of rabies virus from an organ donor to four transplant recipients. *N Engl J Med* 2005; **352**: 1103-1111 [PMID: 15784663 DOI: 10.1056/NEJMoa043018]

144 **Vora NM**, Basavaraju SV, Feldman KA, Paddock CD, Orciari L, Gitterman S, Griese S, Wallace RM, Said M, Blau DM, Selvaggi G, Velasco-Villa A, Ritter J, Yager P, Kresch A, Niezgoda M, Blanton J, Stosor V, Falta EM, Lyon GM 3rd, Zembower T, Kuzmina N, Rohatgi PK, Recuenco S, Zaki S, Damon I, Franka R, Kuehnert MJ; Transplant-Associated Rabies Virus Transmission Investigation Team. Raccoon rabies virus variant transmission through solid organ transplantation. *JAMA* 2013; **310**: 398-407 [PMID: 23917290 DOI: 10.1001/jama.2013.7986]

145 **Zhang J**, Lin J, Tian Y, Ma L, Sun W, Zhang L, Zhu Y, Qiu W, Zhang L. Transmission of rabies through solid organ transplantation: a notable problem in China. *BMC Infect Dis* 2018; **18**: 273 [PMID: 29898712 DOI: 10.1186/s12879-018-3112-y]

146 **Chen S**, Zhang H, Luo M, Chen J, Yao D, Chen F, Liu R, Chen T. Rabies Virus Transmission in Solid Organ Transplantation, China, 2015-2016. *Emerg Infect Dis* 2017; **23**: 1600-1602 [PMID: 28820377 DOI: 10.3201/eid2309.161704]

147 **Saeed B**, Al-Mousawi M. Rabies Acquired Through Kidney Transplantation in a Child: A Case Report. *Exp Clin Transplant* 2017; **15**: 355-357 [PMID: 28411355 DOI: 10.6002/ect.2017.0046]

148 **Amman BR**, Pavlin BI, Albariño CG, Comer JA, Erickson BR, Oliver JB, Sealy TK, Vincent MJ, Nichol ST, Paddock CD, Tumpey AJ, Wagoner KD, Glauer RD, Smith KA, Winpisinger KA, Parsely MS, Wyrick P, Hannafin CH, Bandy U, Zaki S, Rollin PE, Ksiazek TG. Pet rodents and fatal lymphocytic choriomeningitis in transplant patients. *Emerg Infect Dis* 2007; **13**: 719-725 [PMID: 17553250 DOI: 10.3201/eid1305.061269]

149 **Childs JE,** Klein SL, Glass GE. A Case Study of Two Rodent-Borne Viruses: Not Always the Same Old Suspects. *Front Ecol Evol* 2019; **35** [DOI: 10.3389/fevo.2019.00035]

150 **Fischer SA**, Graham MB, Kuehnert MJ, Kotton CN, Srinivasan A, Marty FM, Comer JA, Guarner J, Paddock CD, DeMeo DL, Shieh WJ, Erickson BR, Bandy U, DeMaria A Jr, Davis JP, Delmonico FL, Pavlin B, Likos A, Vincent MJ, Sealy TK, Goldsmith CS, Jernigan DB, Rollin PE, Packard MM, Patel M, Rowland C, Helfand RF, Nichol ST, Fishman JA, Ksiazek T, Zaki SR; LCMV in Transplant Recipients Investigation Team. Transmission of lymphocytic choriomeningitis virus by organ transplantation. *N Engl J Med* 2006; **354**: 2235-2249 [PMID: 16723615 DOI: 10.1056/NEJMoa053240]

151 **Macneil A**, Ströher U, Farnon E, Campbell S, Cannon D, Paddock CD, Drew CP, Kuehnert M, Knust B, Gruenenfelder R, Zaki SR, Rollin PE, Nichol ST; LCMV Transplant Investigation Team. Solid organ transplant-associated lymphocytic choriomeningitis, United States, 2011. *Emerg Infect Dis* 2012; **18**: 1256-1262 [PMID: 22839997 DOI: 10.3201/eid1808.120212]

152 **Tanveer F**, Younas M, Fishbain J. Lymphocytic choriomeningitis virus meningoencephalitis in a renal transplant recipient following exposure to mice. *Transpl Infect Dis* 2018; **20**: e13013 [PMID: 30325104 DOI: 10.1111/tid.13013]

153 **Pinto-Ferreira F**, Caldart ET, Pasquali AKS, Mitsuka-Breganó R, Freire RL, Navarro IT. Patterns of Transmission and Sources of Infection in Outbreaks of Human Toxoplasmosis. *Emerg Infect Dis* 2019; **25**: 2177-2182 [PMID: 31742524 DOI: 10.3201/eid2512.181565]

154 **Robert-Gangneux F**, Dardé ML. Epidemiology of and diagnostic strategies for toxoplasmosis. *Clin Microbiol Rev* 2012; **25**: 264-296 [PMID: 22491772 DOI: 10.1128/CMR.05013-11]

155 **Pappas G**, Roussos N, Falagas ME. Toxoplasmosis snapshots: global status of Toxoplasma gondii seroprevalence and implications for pregnancy and congenital toxoplasmosis. *Int J Parasitol* 2009; **39**: 1385-1394 [PMID: 19433092 DOI: 10.1016/j.ijpara.2009.04.003]

156 **Weiss LM**, Dubey JP. Toxoplasmosis: A history of clinical observations. *Int J Parasitol* 2009; **39**: 895-901 [PMID: 19217908 DOI: 10.1016/j.ijpara.2009.02.004]

157 **Khurana S**, Batra N. Toxoplasmosis in organ transplant recipients: Evaluation, implication, and prevention. *Trop Parasitol* 2016; **6**: 123-128 [PMID: 27722100 DOI: 10.4103/2229-5070.190814]

158 **Robert-Gangneux F**, Meroni V, Dupont D, Botterel F, Garcia JMA, Brenier-Pinchart MP, Accoceberry I, Akan H, Abbate I, Boggian K, Bruschi F, Carratalà J, David M, Drgona L, Djurković-Djaković O, Farinas MC, Genco F, Gkrania-Klotsas E, Groll AH, Guy E, Hirzel C, Khanna N, Kurt Ö, Junie LM, Lazzarotto T, Len O, Mueller NJ, Munoz P, Pana ZD, Roilides E, Stajner T, van Delden C, Villena I, Pelloux H, Manuel O. Toxoplasmosis in Transplant Recipients, Europe, 2010-2014. *Emerg Infect Dis* 2018; **24**: 1497-1504 [PMID: 30014843 DOI: 10.3201/eid2408.180045]

**Footnotes**

**Conflict-of-interest statement:** The authors declare that they have no conflict of interest.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

**Manuscript source:** Invited manuscript

**Peer-review started:** December 22, 2019

**First decision:** February 20, 2020

**Article in press:**

**Specialty type:** Transplantation

**Country of origin:** Croatia

**Peer-review report classification**

Grade A (Excellent): A

Grade B (Very good): B

Grade C (Good): 0

Grade D (Fair): 0

Grade E (Poor): 0

**P-Reviewer:** Hibberd AD, Maggi F **S-Editor:** Wang YQ **L-Editor: E-Editor:**

**Table 1 Clinical manifestations of emerging and neglected zoonoses in non-transplant and transplant population**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pathogen** | **Clinical presentation** | | **Laboratory diagnosis** | **Ref.** |
| **Immunocompetent patients** | **Immunocompromised patients** |
| Vector-borne zoonoses | | | | |
| Tick-borne encephalitis virus | Asymptomatic infection to severe encephalitis | Few data: One cluster of fatal TBE | ELISA (IgM, IgG), Avidity; VNT; RT-PCR | [4,14-16] |
| *Borrelia burgdorferi* | Erythema migrans, arthritis, peripheral neuropathy, acrodermatitis chronica atrophicans, neuroborreliosis | Possible dissemination with severe neurological and cardiac symptoms | ELISA (IgM, IgG); IFA (IgM, IgG); Immunoblot (IgM, IgG); PCR | [4,18-20] |
| *Anaplasma phagocytophilum* | Mostly self-limiting disease, non-specific symptoms, rash, gastrointestinal and CNS involvement | Unusual presentations: Acute respiratory distress syndrome, haemorrhagic manifestations, pancreatitis, acute renal failure, orchitis | Microscopy of peripheral blood (morulae); IFA (seroconversion of 4-fold increase in IgG titer); PCR | [4,26,32,33,43] |
| *Ehrlichia* spp. | Self-limiting febrile illness to fatal multi-organ failure | More frequently severe manifestations: Fatal multiorgan failure, acute respiratory distress syndrome meningoencephalitis, toxic and septic-like syndromes | Microscopy of peripheral blood (morulae); IFA (seroconversion of 4-fold increase in IgG titer); PCR | [4,25,36,37,42] |
| *Rickettsia* spp. | Self-limiting disease, flu-like symptoms, with or without eschar and rash; vasculitis-mediated organ failure | Few data: More frequently severe manifestations, splenic rupture | IFA (IgM, IgG); PCR | [4,49,51] |
| *Orientia tsutsugamushi* | Nonspecific febrile illness to fatal multiorgan failure, eschar, CNS involvement | Few data: Only one case with eschar and renal graft dysfunction | IFA (IgM, IgG); PCR | [4,53,54] |
| Rift Valley Fever virus | Subclinical to severe febrile illness, fatal haemorrhagic fever | Few data: Only one case with meningoencephalitis | ELISA (IgM, IgG); VNT; RT-PCR | [4,59,61] |
| St. Louis encephalitis virus | Majority asymptomatic, febrile illness, aseptic meningitis and encephalitis | Few data: Meningoencephalitis | ELISA (IgM, IgG); VNT; RT-PCR | [4,63,65] |
| Zika virus | Asymptomatic infection to severe neurological disorders | Infectious complications and graft rejection | ELISA (IgM, IgG); VNT; RT-PCR | [4,69-71] |
| Chikungunya virus | Mild febrile illness and polyarthralgia, rarely meningoencephalitis, myocarditis | No impact on graft function | ELISA (IgM, IgG); VNT; RT-PCR | [4,74,75,77,79,80] |
| Dengue virus | Asymptomatic infection to severe fatal illness | More commonly prolonged course with complications and graft rejection | ELISA (IgM, IgG); VNT; NS1 antigen; RT-PCR | [4,82,84-86] |
| West Nile virus | Asymptomatic infection, mild febrile disease, neuroinvasive disease (elderly) | Fatal neuroinvasive disease more frequent | ELISA (IgM, IgG); VNT; Avidity; VNT; RT-PCR | [4,87,96,97,108,109] |
| Usutu virus | Asymptomatic infection, neuroinvasive disease (elderly) | Fatal neuroinvasive disease more frequent | ELISA (IgM, IgG); VNT; RT-PCR | [4,114-119] |
| Eastern equine encephalitis virus | Asymptomatic, neuroinvasive disease (meningitis, encephalitis) | Few data: Neuroinvasive disease | ELISA (IgM, IgG); VNT; RT-PCR | [4,123,124] |
| *Leishmania* spp. | Cutaneous, mucocutaneus and visceral leishmaniasis | The same as in immunocompetent; organomegaly may be less frequent in visceral leishmaniasis | Microscopy; Culture; PCR; IFA (IgM, IgG) | [4,129,130] |
| Non-vector-borne zoonoses | | | | |
| Hepatitis E virus | Asymptomatic infection, fulminant hepatitis,  acute-on-chronic liver failure,  extrahepatic manifestations | Chronic hepatitis, cirrhosis, extrahepatic manifestations | ELISA (IgM, IgG); Immunoblot (IgM, IgG); RT-PCR | [4,131-133,135,136] |
| Rabies virus | Fatal encephalitis | Fatal encephalitis | Microscopy (Negri bodies); DFA (antigen detection); IHC (antigen detection); RT-PCR, RFFIT, FAVN | [4,143-146] |
| Lymphocytic choriomeningitis virus | Asymptomatic infection, nonspecific febrile illness, aseptic meningitis | More severe clinical presentation, hepatitis, meningoencephalitis, multiorgan failure | ELISA (IgM, IgG); IFA (IgM, IgG); RT-PCR | [4,99,151,152] |
| *Toxoplasma gondii* | Asymptomatic, mononucleosis-like symptoms | More severe clinical presentation, cerebral toxoplasmosis, fatal disseminated disease | ELISA (IgM, IgG); IFA (IgM, IgG); Avidity, Immunoblot (IgM, IgG); PCR | [4,156-158] |

CNS: Central nervous system; DFA: Direct immunofluorescence assay; ELISA: Enzyme-linked immunosorbent assay; FAVN: Fluorescent antibody virus neutralization test; IFA: Indirect immunofluorescence assay; IgG: Immunoglobulin G; IgM: Immunoglobulin M; IHC: Immunohistochemistry; NS1: Non-structural protein 1; PCR: Polymerase chain reaction; RT-PCR: Reverse-transcriptase polymerase chain reaction; TBE: Tick-borne encephalitis; RFFIT: Rapid fluorescent focus inhibition test; VNT: Virus neutralization test.