Research Article

The Seroprevalence of Zika Virus Infection among HIV Positive and HIV Negative Pregnant Women in Jos, Nigeria

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Abstract | Zika virus infection (ZIKVI) have been known for years in Africa but data on sero-epidemiology among vulnerable pregnant women is lacking. We aimed to describe the seroprevalence of ZIKVI and associated factors in Jos, North Central Nigeria. A cross-sectional study was performed at Plateau State Specialist Hospital in Jos, North Central Nigeria from August to December 2020. We enrolled a total of 90 (45 HIV positive and 45 HIV negative) pregnant women aged ≥18 and ≤50 years attending antenatal clinic. Ethical approval was obtained and approved by the Health Research Ethics Committee of the hospital. Detection of ZIKV IgG antibodies was done using a commercial sandwich enzyme-linked immunosorbent assay (ELISA) kit to qualitatively analyze Human Zika virus IgG (ZV-IgG) in human serum. A total of 90 pregnant women was recruited, and the overall seroprevalence was (14.4%) for Zika virus (20.0% HIV positive and 8.9% negative) IgG antibodies. A significant association was found with age category among the HIV negative pregnant women p=0.012, and in the history of blood transfusion among the HIV positive participants, p=0.013. No association with educational level, employment, marital and resident, gestational trimester, fever, yellow fever vaccination, rashes and parity was found for anti-ZIKV IgG positivity in the groups. Our results showed high seroprevalence among the pregnant women, an indication that the ZIKV antigen that triggered the antibodies response is in circulation, therefore, suggest the need for ZIKV surveillance and larger study on specific IgM antibodies in Nigeria.

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Introduction

Zika virus is a member of the virus genus Flavivirus, family Flaviviridae, and named after Zika Forest of Uganda, where the virus was first isolated from a sentinel rhesus monkey and from a pool of *Aedes africanus* mosquitoes in the forest in 1947, and was later identified in humans in 1952 in Uganda and the United Republic of Tanzania (Smithburn, 1952) It is spread by daytime-active *Aedes* mosquitoes (*A. aegypti* and *A. albopictus*) (Goeijenbier *et al.*, 2016). Zika virus infection (ZIKVI) became the first major infectious disease linked to human birth defects (spontaneous abortion, stillbirth, hydranencephaly

and microcephaly) to be discovered in more than half a century and created such a global alarm that the World Health Organization (WHO) would declare a Public Health Emergence of International Concern (Gulland, 2019; Lyle *et al*., 2016). By the 1980s, the *Aedes aegypti* also known as (*Ae. Aegypti*) had carried the Zika virus across equatorial Asia (Pakistan to Indonesia) (Olson *et al*.,1981), and to the South Pacific, where it caused major outbreaks in 2013 and 2014 (Roth *et al*., 2014). Brazil confirmed the circulation of Zika virus infection in July 15, 2015 (Duong *et al*., 2016). In just few after, Brazilian authorities detected the neurological disorder Guillain-Barré syndrome (GBS) and microcephaly in some adults and among newborns respectively (WHO, 2016).

Human infection caused by this virus was first reported from Nigeria in 1953, when the viral infection was confirmed in three ill patients (MacNamara, 1954). The majority of human infections are asymptomatic, while evidence have also shown that ZIKV infection can lead to congenital birth abnormalities and severe neurological complications (Rasmussen *et al*., 2016). Although ZIKV has been in circulation for decades, but there is paucity of data on the prevalence of ZIKV in the continent of Africa. Earlier finding in Nigeria have reported 40% of neutralizing antibodies among Nigerian from the Western region (Fagbami, 1979). However, a recent study showed the circulation of Zika virus among HIV-infected population in Nigeria (Mathé *et al*., 2018) and some parts of West Africa (Herrera *et al*., 2017). In view of the potential effects associated with congenital birth defects caused by ZIKVI, there is the need for surveillance in HIV infected pregnant women for epidemiological purposes and public health preparedness and intervention in Africa. However, laboratory diagnosis of ZIKVI is challenging due to the extensive cross-reactivity among the different members of the Flavivirus genus in an endemic region including African countries where the vegetation seems to favor transmission.

The recent emergence of the ZIKVI, and with the consequent rapid spread of the virus throughout the Americas and an increase in the number of infants born with microcephaly creates a potential epidemic with dire consequence for both infant and maternal health globally (Schuler-Faccini *et al*., 2016; Tetro, 2016). While current public efforts aimed at controlling the epidemic which is centered on measures surrounding the vector behavior and ecological factors predisposing to the acquisition of the diseases are ongoing, most resource limited countries are yet to key into this global fight (WHO, 2016; Victora *et al*., 2016; Jouannic *et al*., 2016; Cauchemez *et al*., 2016). There exist gaps in in the knowledge regarding ZIKV infection, these include; the risk of complications in mother, fetus and newborn; the clinical spectrum of disease presentation in the general population and HIV infected pregnant women, including the mechanisms of vertical transmission. And with the current paucity of data on ZIKVI, we set to carry out a pilot study on the seroprevalence so as to contribute to sero-epidemiological data in pregnancy on Zika virus from Nigeria. Therefore, the study aimed to determine sero-prevalence (anti-ZV-IgG) of Zika virus infection and associated factors among pregnant women with or without fever.

Materials and Methods

The cross-sectional study was carried at Plateau State Specialist Hospital in Jos metropolis, Nigeria. We enrolled a total of 90 (45 HIV positive and 45 HIV negative) pregnant women attending antenatal clinic. Ethical approval was obtained and approved by the Health Research Ethics Committee of the hospital. The consent of all the participating subjects were obtained using consent form before the collection of their blood samples. The study excluded all pregnant women who did not give consent. Blood samples were collected from participants aged ≥18 years and ≤50 from August to December 2019 through venipuncture, and well-structured questionnaire was used to collect biodata and any clinical symptoms of a ZIKV infection. The collected 5ml blood samples in plain tubes, were centrifuged at 10 minutes at 3000 rpm, the serum was separated into cry-vials, labeled and then stored at -80 ^{o}C to avoid loss of bioactivity and contamination at the research laboratory, Institute of Human virology Nigeria, Plateau Sate Specialist hospital before being tested for ZIKV IgG. The samples were Screened for Zika virus immunoglobulin (IgG) using a commercial sandwich enzyme linked immunosorbent assay (ELISA) kit (My Bio Source Inc San Diego, USA) to qualitatively analyze Human Zika virus IgG (ZV-IgG) in human serum. The standard positive and negative control were included for quality control. The calculated OD value of positive cut off was set at 0.172, and negative at 0.140 and equivocal was from 0.140-0.172. The result was interpreted as any absorbance value greater than 0.172 as positive, value less than

0.140 considered as negative, and indeterminate was between 0.140-0.172.

Data analysis

The collected data was analyzed using SPSS version 23 (IBM, Armonk, NY), and differences between groups were identified using chi-square test, with the threshold of p≤ 0.05 considered statistically significant.

Results and Discussion

Total number of pregnant women included in the study were 90, and the overall seroprevalence was 13/90 (14.4%) for Zika virus infection (20.0% HIV positive and 8.9% negative). The results of serostatus of the patients were compared in relation to demographic factors (Table 1). There was no significant association between the demographic and serostatus among the HIV positive pregnant women, except for age category among the HIV negative women, p=0.012. Comparison of the age groups showed higher prevalence of ZV-IgG antibodies to ZIKV in the age category of aged ≥31years (21.4%) among HIV positive, and negative women (35.3%). Participants with Tertiary education had the highest prevalence 25.0% and 15.0% among HIV positive, HIV negative pregnant women respectively. For employment status, the highest prevalence (21.7%) was among employed HIV positive, and negative women (11.8%), those who reside in urban area showed the highest seroprevalence (20.5%) among HIV positive, and all the HIV negative reside in Jos. Table 2 showed results of serostatus and factors associated with ZIKVI, and significant was only observed with history of no blood transfusion (P= 0.013), and gestation period (trimester), p= 0.070. The pregnant women within the first Trimester had the highest prevalence 40.0%, third trimester had 30.0% in HIV positive, and 10.8% in the third trimester among HIV negative pregnant women. For women who experienced fever, the prevalence was 33.3% in HIV positive, 3 (9.1%) in the negative group. For those who had yellow fever vaccine, the seroprevalence (21.1%) was higher in the HIV positive, and (9.5%) in the negative group. There was report of rashes recorded in (20.0%) in the HIV negative pregnant women. We did not observe a statistically significant differences in relation to number of number of pregnancies (parity), but highest was observed in those with ≤ 3 (20.5%) seroprevalence in the HIV positive, 14.3% in the HIV negative pregnant women.

Zika virus infection (ZIKVI) is an emerging disease that is transmitted to humans by mosquito (*Aedes aegypti),* that was thought to be associated with relatively mild clinical conditions. However, it attracted global attention when it was linked to human birth abnormalities (microcephaly), following the 2015 Zika virus (ZIKV) outbreak in Brazil, Latin America (WHO, 2015). This report of ZIKV outbreak in Brazil triggered public health concerns worldwide. Though no reported cases of ZIKV in Nigeria public health system but cases of microcephaly have been observed among neonates (unpublished data) in the tertiary hospitals. And because there has been no active surveillance for ZIKV at the time, it was difficult to establish the etiology of the disease, however the presence of the vector in some parts of the country represents a potential source of risk. The present study was performed on pregnant women (both HIV positive and negative), and were screened for any possibility of past infection (anti-ZV-IgG), or any subclinical evidence suggestive of manifestation of ZIKV infection.

Our study revealed 14.4% of ZV-IgG antibodies among the pregnant women (20.0% HIV positive, 8.9% HIV negative. The findings of this study showed previous infection to ZIKV, although the presence of anti-ZV-IgG within the study population of pregnant women was not expected to correlated with any clinical symptoms since it is an immune defense response. We did observe 2 participants in the HIV negative group with rashes which may not be related to the findings, however, these antibodies suggest presence protective immunity to the participants which also is an indication of exposure to circulating virus in Nigeria.

Although the diagnosis of ZIKV infections using serological assays remains challenging due to reported cross-reactivity between flaviviruses which has complicated the interpretation of results obtained. Also, previous exposure to some mosquito borne flavivirus human pathogens such as Dengue (DENV) and Yellow Fever (YFV) viruses could pose serious challenge to interpretation of IgG antibodies findings. Furthermore, the obvious clinical presentations of ZIKV infection apart from being subclinical could mimic malaria which is endemic. The presence of some these flaviviruses as well as their vaccines especially

Table 1: *The sero-prevalence of Zika virus infection in relation to socio-demographic factors among HIV positive and HIV negative pregnant women in Jos, Nigeria.*

Variables	HIV positive negative pregnant			HIV negative pregnant women		
	Samples No.	Positive No. (%)	P value	Samples No.	Positive No. (%)	P value
Age group (years)						
≤ 30	17	3 (17.6)	0.129	28	2(7.1)	0.012
≥31-50	28	6 (21.4)		17	6(35.3)	
Educational level						
Primary	6	1 (16.7)	0.916	3	0 (0.0)	0.422
Secondary	31	6 (19.4)		22	1 (4.5)	
Tertiary	8	2 (25.0)		20	4 (15.0)	
Employment status						
Employed	23	5 (21.7)	0.766	17	2 (11.8)	0.597
Unemployed	22	4 (18.2)		28	2 (7.1)	
Marital status						
Married	45	9 (20.0)	-	44	4 (9.1)	0.679
Single	0	0		1	0 (0.0)	
Residence						
Urban	44	9 (20.5)	0.613	45	4 (8.9)	-
Rural	1	0 (0.0)	0	0	0	

Table 2: *The sero-prevalence of Zika virus infection in relation to risk factors among HIV positive and HIV negative pregnant women in Jos, Nigeria.*

	HIV positive negative pregnant			HIV negative pregnant women		
Variables	**Samples No.**	**Positive No. (%)**	**P value**	**Samples No.**	**Positive No. (%)**	**P value**
History blood transfusion						
Yes	3	0 (0.0)	0.013	7	1 (14.3)	0.585
No	42	9 (21.4)		38	3 (7.9)	
Gestational trimester						
1st trimester	5	2 (40.0)	0.070	6	0 (0.0)	0.622
2nd trimester	20	1 (5.0)		2	0 (0.0)	
3rd trimester	20	6 (30.0)		37	4 (10.8)	
Any fever						
Yes	12	1 (8.3)	0.264	12	1 (8.3)	0.937
No	33	3 (9.1)		33	3 (9.1)	
Yellow fever vaccine						
Yes	13	3 (21.1)	0.742	24	2 (8.3)	0.889
No	32	6 (18.8)		21	2 (9.5)	
Sign of rashes						
Yes	0	0	-	10	2 (20.0)	0.162
No	45	9 (20.0)		35	2 (5.7)	
Parity						
≤ 3	39	8 (20.5)	0.880	38	3 (7.9)	0.585
4 – 6	5	1 (20.0)		7	1 (14.3)	
≥ 7	1	0 (0.0)		0	0	

yellow fever vaccine have been known to show cross-reactivity capable of generating false positivity serologically (Dejnirattisai *et al*., 2016). This claim has also been demonstrated in earlier study in Nigeria supporting previous exposure to flavivirus (Baba *et al*., 2013). Although earlier finding showed high prevalence in a study carried out in Western Nigeria, where 31.0% was reported (Fagbami, 1979). Our finding was higher than a recent work done in North-Central Nigeria with the prevalence of 3.0% of anti-ZV-IgG among pregnant women (Mathé *et al*., 2018). It should also be noted that cross-reactivity resulting to false positive IgG could be a contributing factor to this high prevalence being observed in this study. Although this argument cannot rule out Jos metropolis in North Central Nigeria from being susceptible to ZIKVI. This study therefore, support the earlier report that there is an ongoing transmission of ZIKV in the region (Herrera *et al*., 2017). Interestingly, we also observed higher anti-ZV-IgG compared to a study done in neighboring Cameroon (5.0%) (Mathé *et al*., 2018; Gake *et al*., 2017). The exact reasons for high prevalence are not known, but may be due to increased exposure to high outdoor activities by women during farming. However, this finding is in agreement with earlier study in Brazil and Puerto Rico that showed high urban transmission cycle and a preponderance of zika virus infection among females (Lozier *et al*., 2016). In a similar way, data suggesting higher risk of acquiring ZIKV infection in pregnant women compared to the non-pregnant population after exposure to Aedes mosquitoes are lacking, except for the obvious low immunity experienced at pregnancy. In this study we overserved higher prevalence among the HIV positive pregnant women compared to none HIV negative. Earlier finding showed that people with HIV infection do not appear to have any greater risk of infection or greater complication than the HIV negative or general population, and even with other flaviviruses (Dengue virus, Yellow Fever virus, or West Nile virus) (Rothan *et al*., 2018). Also, the presence of these IgG antibodies during pregnancy suggest protection against the risk of congenital abnormalities in a child born to mothers irrespective of clinical symptoms (Shapiro-Mendoza *et al*., 2017).

The greater proportion of women aged ≥31years had more positive IgG antibodies, and this may be due to greater outdoor activities and continuous exposure to these viruses thereby eliciting this protective immunity to the mothers and unborn children. In the education level and employment status, higher seroprevalences was observed in the tertiary education and employed in both groups, suggestive of well informed and exposed that may culminate into better health seeking behavior than the less educated and unemployed individuals. Also, we observed higher seroprevalence at first trimester (40.0%) among the HIV positive, and 10.8%) in the third trimester of HIV negative. We do not have evidence to substantiate this variation at gestational period, but it could be interesting to note that babies born theses mothers will have a privilege of having protective maternal antibodies. Interestingly, since infections at first trimester have severe consequences, the high presence of ZV-IgG suggest high immune protection to the fetus, and decreased consequences of birth defects due to ZIKVI (Noronha *et al*., 2018), also those with high antibodies in the third trimester (HIV negative) may also succeed in transferring the maternal antibodies to the babies at birth. Few studies have reported more clinical symptoms at first trimester in most infections, while others are on the contrary (Lin *et al*., 2017). Although we did not measure the transfer of IgG at pregnancy or how it impacts on placental transfer but its presence suggest that the newborn will benefit protection from the mother's humoral immunity (Chibueze *et al*., 2017). The presence of IgG in pregnancy may as well contribute to fetus protection from some congenital ZIKV associated birth defects and the infant from ZIKV infection (Singh *et al*., 2019).

Again, one of the common symptoms of ZIKV infection is rash (maculopapular rash) in pregnant women but we did observe rashes among in the HIV negative which may not be connected to past exposure to ZKV, though we did not test for IgM to validate this claim. However, common symptoms among pregnant women with suspected or confirmed ZIKV infection could be fever, rash, and arthralgia. We observed 33.3% cases of fever with no statistical difference, but these may be due to malaria or fever induced by other antigens in the individuals. Also, these findings are consistent with those of an earlier study that some individuals may have unexplained febrile illness which suggest that ZIKV and/or related viruses are widely in circulation in Nigeria (Savage *et al*., 1992; Fagbami *et al*., 1977). This data highlights the urgent need for routine screening of ZIKVI in antenatal care, and prompt surveillance activities for better epidemiological understanding of

ZIKV in African region where the vectors are in wide circulation. It is worthy to mention that, to the best of our knowledge, our study is the first description of ZIKV seroprevalence among HIV-positive and negative pregnant women in Nigeria, and this serves as strength to the small sample size. Despite the relatively small sample size and the impossibility of excluding cross-reactivity with other flaviviruses from influencing the serological assay results, this study has provided insight into the possibility of previous infection with ZIKV antigen occurring among HIV infected pregnant women in Nigeria. Though, we only tested for IgG antibodies, therefore we could not determine the disease burden of active infection among the study population.

Conclusions and Recommendations

The study showed high prevalence of ZV-IgG antibodies among pregnant women in Jos metropolis, suggesting an ongoing transmission of the virus. This data is considered epidemiologically important in providing clues as to the possible presence of the ZIKV circulating IgG antibodies in West Africa. However, with the presence of the arbovirus vectors in the country, the presence of protective antibodies, we propose the need for continuous surveillance for ZIKV and other flaviviruses. Further larger research on ZIKV specific antigen may provide a broader understanding of ZIKV infection in pregnancy, and to inform the creation of effective and evidence-based strategies, recommendations, health guidelines, and policies targeting the management of maternal ZIKVI.

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Author's Contribution

JA-O conceived, designed the analysis and manuscript preparation. DYM and ANC collected the data. OOA assisted in data collection and manuscript review. JA and HZ contributed to analysis tools and manuscript review. OIU and OJO performed the analysis and manuscript review. JOE read and approved the manuscript.

Conflicts of interest

The authors have declared no conflicts of interest.

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References

Baba, M., C.H. Logue, B. Oderinde, H. Abdulmaleek, J. Williams, J. Lewis, T.R. Laws, R. Hewson, A. Marcello and P. D'Agaro. 2013. Evidence of arbovirus co-infection in suspected febrile malaria and typhoid patients in Nigeria. J. Infect. Dev. Ctries, 7(1): 51–59. https://doi.org/10.3855/jidc.2411

Cauchemez, S., M. Besnard, P. Bompard, T. Dub, P. Guillemette-Artur, D. Eyrolle-Guignot, H. Salje, M.D.V. Kerkhove, V. Abadie, C. Garel, A. Fontanet and H-P. Mallet. 2016. Association between Zika virus and microcephaly in French Polynesia, 2013- 15: A retrospective study. Lancet, 387(10033): 2125-2132. https://doi.org/10.1016/S0140-6736(16)00651-6

Chibueze, E.C., V. Tirado, K.S. Lopes, O.O. Balogun, Y. Takemoto, T. Swa, A. Dagvadorj, C. Nagata, N. Morisaki, C. Menendez, E. Ota, R. Mori and O.T. Oladapo. 2017. Zika virus infection in pregnancy: A systematic review of disease courses and complications. Reprod. Health, 14(28): 1-14. https://doi.org/10.1186/s12978-017-0285-6

Dejnirattisai, W., P. Supasa, W. Wongwiwat, A. Rouvinski, G. Barba-Spaeth, T. Duangchinda, A. Sakuntabhai, V-M. Cao-Lormeau, P. Malasit, F.A. Rey, J. Mongkolsapaya and G.R. Screaton. 2016. Dengue virus sero-cross-reactivity drives antibody-dependent enhancement of infection with zika virus. Nat. Immunol., 7(9): 1102-1108. https://doi.org/10.1038/ni.3515

Duong, V., P. Dussart and P. Buchy. 2016. Zika virus in Asia. Int. J. Infect. Dis., 54: P121-128. https://doi.org/10.1016/j.ijid.2016.11.420

Fagbami, A., O. Tomori and A. Fabiyi. 1977. Virological and Clinical observations during an outbreak of Dengue and Dengue-like illness at Abeokuta. Nig. Med. J., 7(4): 380-383.

Fagbami, H.A., 1979. Zika virus infections in Nigeria: Virological and seroepidemiological investigations in Oyo State. J. Hyg., (Lond). 83(2): 213–219. https://doi.org/10.1017/S0022172400025997

Gake, B.M., A. Vernet, I. Leparc-Goffart, J.F. Drexler, E.A. Gould, P. Gallian and X. de Lamballerie. 2017. Low seroprevalence of Zika virus in Cameroonian blood donors. Braz. J. Infect. Dis., 21(4): 481–483. https://doi.org/10.1016/j.bjid.2017.03.018

Goeijenbier, M., L. Slobbe, A. van der Eijk, M. de Mendonca Melo, G.P.M. Koopmans and C.B.E.M. Reuske. 2016. Zika virus and the current outbreak: An overview. Neth. J. Med., 74(3): 10-18.

Gulland, A., 2016. Zika virus is a global public health emergency, declares WHO. BMJ. pp. 352-357. https://doi.org/10.1136/bmj.i657

Herrera B.B., C.A. Chang, D.J. Hamel, S. Mboup, D. Ndiaye, G. Imade, J. Okpokwu, O. Agbaji, A.K. Bei and P.J. Kanki. 2017. Continued transmission of Zika virus in humans in west Africa, 1992–2016. J. Infect. Dis., 215(10): 1546–1550. https://doi.org/10.1093/infdis/jix182

Jouannic, J.M., S. Friszer, I. Leparc-GoffartI, C. Garel and D. Eyrolle-Guignot. 2016. Zika virus infection in French Polynesia. Lancet, 387: 1051–1052. https://doi.org/10.1016/S0140-6736(16)00625-5

Lin, Z.H., A.P. Tambyah, L.E. Yong, A. Biswas and S.Y. Chan. 2017. A review of Zika virus infections in pregnancy and implications for antenatal care in Singapore. Singapore Med. J., 58(4): 171-178. https://doi.org/10.11622/smedj.2017026

Lozier, M., L. Adams, M.F. Febo, J. Torres-Aponte, M. Bello-Pagan, K.R. Ryff, J. Munoz-Jordan, M. Garcia, A. Rivera, J.S. Read, S.H. Waterman, T.M. Sharp and B. Rivera-Garcia. 2016. Incidence of Zika virus disease by age and sex – Puerto Rico, November 1, 2015–October 20, 2016, MMWR. Morb. Mortal. Wkly. Rep., 65(44): 1219–1223. https://doi.org/10.15585/mmwr.mm6544a4

Lyle, R., Petersen, J. Denise, Jamieson and M. Ann. 2016. Powers and Margaret A. Honein. Zika virus. N. Engl. Med., 374(16): 1552-1563. https://doi.org/10.1056/NEJMra1602113

MacNamara, F.N., 1954. Zika virus: A report on three cases of human infection during an epidemic of jaundice in Nigeria. Trans. R. Soc. Trop. Med. Hyg., 48: 139-145. https://doi.org/10.1016/0035-9203(54)90006-1

Mathé, P., D.Z. Egah, J.A. Müller, N.Y. Shehu, E.T. Obishakin, D.D. Shwe, V.C. Pam, M.O. Okolo, C. Yilgwan, S.S. Gomerep, J. Fuchs, I. Abok, K.I. Onyedibe, E.J. Olugbo, S.E. Isa, S.S. Machunga-Mambula, AC.I. Ttah, J. Münch, S. Oguche and M. Panning. 2018. Low Zika virus seroprevalence among pregnant women in North Central Nigeria, 2016. J. Clin. Virol., 105(2018): 35–40. https://doi.org/10.1016/j.jcv.2018.05.011

Noronha, L.D., C. Zanluca, M. Burger, A.A. Suzukawa, P.Z. Rebutini, I.M. Novadzki, L.S. Tanabe, M.M. Presibella and C.N.D.D. Santos. 2018. Zika virus infection at different pregnancy stages: Anatomopathological findings, target cells and viral persistence in placental tissues. Front. Microbiol., 9: 2266. https://doi.org/10.3389/fmicb.2018.02266

Olson, J.G., T.G. Ksiazek, Suhandiman and Triwibowo. 1981. Zika virus, a cause of fever in Central Java, Indonesia. Trans. R. Soc. Trop. Med. Hyg., 75: 389–393. https://doi.org/10.1016/0035-9203(81)90100-0

Rasmussen, A.S., J.D. Jamieson, A.M. Honein and R.L. Petersen. 2016. Zika virus and birth defects–reviewing the evidence for causality. N. Engl. J. Med., 374(20): 1981–1987. https://doi.org/10.1056/NEJMsr1604338

Roth, A.A., Mercier, C. Lepers, D. Hoy, S. Duituturaga, E. Benyon, L. Guillaumot and Y. Souarès. 2014. Concurrent outbreaks of dengue, chikungunya and Zika virus infections an unprecedented epidemic wave of mosquito-borne viruses in the Pacific 2012–2014. Eur. Surveill. 19(41): 20929. https://doi.org/10.2807/1560-7917.ES2014.19.41.20929

Rothan, H.A., M.R.M. Bidokhti and S.N. Byrareddy. 2018. Current concerns and perspectives on Zika virus co-infection with arboviruses and HIV. J. Autoimmun., 89: 11-20. https://doi.org/10.1016/j.jaut.2018.01.002

Savage, H.M., V.I. Ezike, A.C. Nwankwo, R. Spiegel and B.R. Miller. 1992. First record of breeding populations of Aedes albopictus in continental Africa: implications for arboviral transmission. J. Am. Mosq. Contr. Assoc., 8(1): 101-103.

Schuler-Faccini, L., E.M. Ribeiro, I.M.L. Feitosa, D.D.G. Horovitz, D.P. Cavalcanti, A. Pessoa, M.J.R. Doriqui, J.I. Neri, J.M. de Pina Neto, H.Y.C. Wanderley, M. Cernach, A.S. El-Husny, M.V.S. Pone, C.L.C. Serao and M.T.V.

Sanseverino. 2016. Possible association between Zika virus infection and microcephaly- Brazil, 2015. MMWR Morb. Mortal. Wkly. Rep., 65(3): 59-62. https://doi.org/10.15585/mmwr.mm6503e2

Shapiro-Mendoza, C.K., E.M. Rice, R.R. Galang, C.A. Fulton, K. VanMaldeghem, V. Prado, E. Ellis, S.M. Anesi, M.R. Simeone, E.E. Petersen, R.S. Ellington, M.A. Jones, T. Williams, S. Reagan-Steiner, J. Perez-Padilla, C.C. Deseda, A. Beron, J.A. Tufa, A. Rosinger, M.N. Roth, C. Green, S. Martin, D.C. Lopez, L. deWilde, M. Goodwin, H.P. Pagano, T.C. Mai, C. Gould, S. Zaki, N.L. Ferrer, S.M. Davis, E. Lathrop, K. Polen, D.J. Cragan, M. Reynolds, B.K. Newsome, M.M. Huertas, J. Bhatangar, M.A. Quiñones, F.J. Nahabedian, L. Adams, M.T. Sharp, W.T. Hancock, A.S. Rasmussen, A.C. Moore, J.D. Jamieson, L.J. Munoz-Jordan, H. Garstang, A. Kambui, C. Masao, A.M. Honein and D. Meaney-Delman. 2017. Pregnancy outcomes after maternal Zika virus infection during pregnancy, U.S. Territories, January 1, 2016- April 25, 2017. MMWR Morb. Mortal. Wkly. Rep., 66: 615–621.

Singh, T., C.A. Lopez, C. Giuberti, M.L. Dennis, H.L. Itell, H.J. Heimsath, H.S. Webster, H.K. Roark, P.R.M. de Vargas, A. Hall, R.G. Corey, G.K. Swamy, R. Dietze, H.M. Lazear and S.R. Permar. 2019. Efficient transplacental IgG transfer in women infected with Zika virus during pregnancy. PLoS Negl. Trop. Dis., 13(8): e0007648. https://doi.org/10.1371/journal.pntd.0007648

Smithburn, K.C., 1952. Neutralizing antibodies against certain recently isolated viruses in human sera of human beings residing in East Africa. J. Immunol., 69: 223-234.

Tetro, J.A., 2016. Zika and microcephaly: Causation, correlation, or coincidence? Microbes Infect. 18(3): 167-168. https://doi.org/10.1016/j.micinf.2015.12.010

Victora, C.G., L. Schuler-Faccini, A. Matijasevich, E. Ribeiro, A. Pessoa and F.C. Barros. 2016. Microcephaly in Brazil: how to interpret reported numbers? Lancet, 387: 621-624. https://doi.org/10.1016/S0140-6736(16)00273-7

WHO, 2015. Epidemiological update: Zika virus infection, 16 October 2015.

WHO, 2016. Zika virus microcephaly and Guillain-Barré Syndrome, Geneva: March 17, 2016.