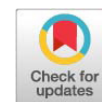


Research Article



Prevalence of Hepatitis D Virus in Hepatitis B Positive Pregnant Women Attending Antenatal Clinic in Ogbomosho, Oyo State, Nigeria

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Abstract | Hepatitis D virus (HDV) and Hepatitis B virus (HBV) infections pose a significant global health challenge with predominant prevalence in Nigeria. It is a major health concern in pregnant women and HBV-coinfected individuals. Studies have shown that pregnant women serve as a reservoir for the persistence and transmission of both viruses worldwide. Both viruses are transmitted through contact with infected blood/ bodily fluids but majorly from Mother-To-Child-Transmission (MTCT). This study aimed at investigating prevalence of HDV in Hepatitis B positive pregnant women attending LAUTECH teaching hospital antenatal clinic in Ogbomosho, Oyo State, Nigeria. A total of 180 serum samples were collected from pregnant women. A five-panel rapid diagnostic kit were used to assay for Hepatitis B surface antigen (HBsAg), Hepatitis B surface antibody (HBsAb), Hepatitis B e antigen (HBeAg), Hepatitis B e antibody (HBeAb) and Hepatitis B core antibody (HBcAb) markers, Enzyme-Linked Immunosorbent Assays (ELISA) kit were used for the detection of HDV IgG antibodies. Polymerase chain reaction (PCR) was carried out in the HBsAg positive and HDV seropositive samples. Statistical analysis was done using the SPSS software, descriptive analysis was done for categorical data to obtain prevalence. Statistical significance was determined with the Chi-square test with the level of significance set at $P \leq 0.05$. HBsAg, HBeAb and HBcAb markers of HBV infection were detected in 13.9% ($n = 25/180$), 2.8% ($5/180$) and 5% ($9/180$) respectively. The prevalence of HDV-IgG in HBV-positive pregnant women was 36% ($n = 9/25$). Molecular detection of HBV DNA was 12% ($3/25$) while all HBV positive samples were HDV RNA negative. This study shows a high prevalence of HDV-IgG implying that a significant proportion of HBV-infected pregnant women had been exposed to HDV at some point. It underlines the need of an extensive surveillance system and further studies.

Received | December 09, 2024; **Accepted** | January 13, 2025; **Published** | January 22, 2024

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Citation | Salami, Z.T., O.O. Opaleye, O. Ojurongbe, A.O. Olowe and T.A. Olayinka. 2025. Prevalence of hepatitis D virus in hepatitis B positive pregnant women attending antenatal clinic in Ogbomosho, Oyo State, Nigeria. *Hosts and Viruses*, 12: 62-69.

DOI | <https://dx.doi.org/10.17582/journal.hv/2025/12.62.69>

Keywords: Pregnant women, Hepatitis B virus, Hepatitis D virus, Ogbomosho, Nigeria, Mother-to-child-transmission (MTCT)



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Introduction

Hepatitis D virus (HDV) has eight reported genotypes with unexplained variations in their pathogenicity and geographical distribution (Caviglia *et al.*, 2022). Rates of HDV infection is high in regions where HBV is endemic, prevalence of HDV among HBV carriers in West-Africa is reported to be between 3-30% (Sagnelli *et al.*, 2021).

HDV is a defective RNA and considered to be a satellite (sub viral agent) because it solely depends on expression of Hepatitis B virus surface antigen (HBsAg) in the same cell to propagate and complete its lifecycle (Mentha *et al.*, 2019).

The Hepatitis D virion is composed of a coat of HBV envelope proteins surrounding the nucleocapsid, which consists of a single-stranded, circular RNA genome with delta antigen (Sausen *et al.*, 2022).

Hepatitis B virus (HBV); small enveloped, pleomorphic virus. It is a major global health problem responsible for liver morbidity and mortality worldwide (Kyaw *et al.*, 2020). About 300 million are estimated to be living with HBV globally with 6.1% prevalence in sub regions of Africa (Amponsah, 2021; WHO, 2024).

HDV can occur either via simultaneous infection with HBV (co-infection) or superimposed on chronic hepatitis B or hepatitis B carrier state (super-infection) (Mentha *et al.*, 2019). Both virus main route of transmission is from Mother-To-Child-Transmission (MTCT) with HDV increasing the risk of MTCT and severe hepatitis. The risk increases with elevated HBV DNA levels especially in the third trimester of pregnancy (Sirilert and Tongsong, 2021).

Several studies suggest that HBV can increase adverse outcomes in pregnancy, such as intrahepatic cholestasis of pregnancy, gestational diabetes and preterm birth. Such associations seem to be related to the activity of the HBV. Pregnancy is said to modify the natural course of HBV infection; especially flare up of hepatitis (Sirilert and Tongsong, 2021).

The risk of MTCT of chronic carriers of HBV (the HBsAg-positive mothers) to their babies has been estimated to be as high as 90% in cases of no immunoprophylaxis in the newborns. The transmission

can occur in utero, during labor and delivery and after birth (Jourdain *et al.*, 2019).

HDV infection and co-infection is not well documented, especially in Nigeria where HDV is not routinely diagnosed. HDV global prevalence is reported to be 5% and a recent report shows 9% HDV prevalence in the general population in South-western Nigeria (Andernach *et al.*, 2014; Opaleye *et al.*, 2016).

Although coinfection mostly leads to the eradication of both viruses, the majority of patients with HDV superinfection progress to chronic HDV infection and hepatitis, usually worsening the pre-existing HBV-related liver damage. Persisting infection leads to the establishment of chronic hepatitis D (CHD), which significantly increases the risk of cirrhosis, hepatocellular carcinoma and acute liver failure, leading to a reduced life expectancy (Okonkwo *et al.*, 2022; Ramachandran *et al.*, 2020).

However, several studies suggest that only a fraction of patients are tested for anti-HDV, such that HDV infection remains largely underdiagnosed. In general, the awareness of HDV is poor compared to other hepatitis viruses, such as HBV. This applies to both developed and developing countries (Lempp *et al.*, 2021).

In studies of pregnant women, the prevalence of HDV varies significantly by region. A study from Iran reported a 5.8% prevalence of HDV among HBV-infected pregnant women (Alavian *et al.*, 2013). In contrast, a Turkish study found 3.4% prevalence (Stockdale *et al.*, 2020). These variations underscore the importance of regional epidemiological data in understanding HDV's impact on pregnancy.

This study aimed at investigating the prevalence of viral hepatitis D among hepatitis B positive pregnant women attending LAUTECH teaching hospital antenatal clinic.

Materials and Methods

Study area and site

The study area was LAUTECH teaching hospital antenatal clinic, Ogbomosho, Oyo state, Nigeria. The study was conducted at HRH-CERID Laboratory, College of Health Science LAUTECH, Ogbomosho.

Inclusion and exclusion criteria

Inclusion of participants was based on informed consent given by the pregnant women prior to filling questionnaire and sample collection. Pregnant women who did not give their consents were excluded.

Sample size and collection

Sample size of 180 with attrition accounted for was calculated using the formula, $N = Z^2 P (1-P) / d^2$. $P = 12\% = 0.12$ was used (Oluremi *et al.*, 2020; Munaro and William, 1997). Non-randomized sampling and consecutive sampling technique was employed in recruiting the study participants; in which every subject meeting inclusion criteria was selected until required sample size was achieved. A total of 180 serum samples were collected from consenting pregnant women in LAUTECH teaching hospital antenatal clinic. Participants were not receiving antiviral treatments during sample collection and most of them had no knowledge of Hepatitis B and D. Each pregnant women were bled via venepuncture, five (5ml) whole blood was collected from each participant into EDTA bottles; serum was subsequently harvested as early as possible and transferred into 2ml cryovial, labelled and stored at 4 °C until tested. Demographic data, knowledge of both HDV and HBV with risk factors was obtained using questionnaires. Samples were collected from January 2023 to August 2023.

Serology testing

To detect HBV markers, samples were analysed using rapid diagnostic test (RDT) kits. Markers tested for were hepatitis B surface antigen (HBsAg), hepatitis B surface antibody (HBsAb), hepatitis B e antigen (HBeAg), hepatitis B e antibody (HBeAb) and hepatitis B core antibody (HBcAb). Samples positive for HBsAg were further screened for HDV-IgG using a research laboratory HDV IgG enzyme-

linked immunosorbent assay (ELISA) kit (Melson medical, Shanghai, China). Test was done according to manufacturer's instruction using an ELISA washer. The optical density was read at 450nm within 15 minutes after stopping the reaction.

Polymerase chain reaction for HBV

DNA was extracted from 200µl serum using the QIAmp DNA mini kit (Qiagen, Hilden, Germany) according to the manufacturer's instruction. The extracted products were stored at -80°C before use.

Samples positive for both HBV markers and HDV-IgG and positive only for HBV markers were assayed for HBV DNA using Nested PCR assay with primers in the region of overlap between the S-gene and P-gene designed to amplify 89bp product (Table 1).

The first-reaction PCR was performed in a total volume of 20µl with a cycling condition of 95 °C for 3 mins, 94°C for 30 sec, 56°C for 30 sec, 72°C for 30secs, 72°C for 5 mins for 30 cycles, 10°C for hold. Same cycling condition for first reaction was used for second reaction. The detection of HBV DNA was successfully validated by Quality Control for Molecular Diagnostics round robin tests, an independent international External Quality Assessment (EQA)/ Proficiency Testing (PT) organisation. Gel electrophoresis was used to visualize amplified band in the result templates using 100bp ladder of known lengths.

RT-PCR and nested PCR for HDV

RNA was extracted from 140µl serum using the QIAmp viral RNA kit (Qiagen, Hilden, Germany) according to the manufacturer's instruction. The extracted products were stored at -80°C before use.

Table 1: Primer sequences.

Primer name	Sequence (5'-3')	Polarity	Location
HBV primers			
HBV-18	CTG TAT CTT CCT GCT GGT GGC T	Sense	9935-9957
HBV-16	GCA GTA TGG ATC GGC AGA GGA	Anti-sense	1824-1844
HBV-1	CTG CTG GTG GCT CCA GTT CAG GA	Sense	256-278
HBV-17	GGG GTT GCG TCA GCA AAC ACT	Anti-sense	1601-1621
HDV primers			
HDV-04	GGATGCCCAGGTCGGACCG	Anti-sense	856-874
HDV-05	AAGAAGAGRAGCCGCCCCGY	Sense	1159-1179
HDV-06	ATGCCATGCCGACCCGAAGA	Sense	888-907
HDV-07	GGGGAGCGCCCGGDGGCGG	Anti-sense	1104-1122

Source: NCBI GenBank.

HCV RNA detection of samples positive for both HBV markers and HCV-IgG was performed using two different PCR assay: A one-step RT-PCR and nested PCR with primers designed for the amplification of a highly conserved region of the HCV genome (Table 1). PCR products was analysed on 1.5% agarose gel.

Data analysis

All data generated from this study were analyzed using packages within statistical package for social sciences (SPSS) version 22.0 statistical software (SPSS, Inc, Chicago, IL, USA). Descriptive analysis and chi-square was used for test of association. Significance was accepted at the level of $P \leq 0.05$ and X^2 is the Pearson chi square value. Descriptive analysis was presented as simple percentages. Graph pad prism (Prism5 software version 5.01, graphpad software, San Diego California, USA) was used to construct a contingency table to analyse the validity (accuracy) of ELISA and RDT as initial screening tool (Table 4).

Results and Discussion

Characteristics of the study participant

The total study participants had a median age of 30.5 years (16-45). Of the 180 pregnant women, 7% (13/180) were in the first trimester, 31% (56/180) were in the second trimester and 62% (111/180) were in the third trimester. Most of the participants 58% (104/180) were in the age group 26-35 years.

Seroprevalence of HBV and HDV

The Seroprevalence of HBsAg marker was highest in participant 13.9% ($n = 25/180$), with HBcAb having a prevalence of 5% (9/180) and HBeAb having a prevalence of 2.8% (5/180) (Table 2). Participant within the age group 26-35 years had a highest prevalence (6.1%) of HBsAg (11/180). Four participants 16% (4/25) were positive for HBsAg, HBeAb, HBcAb and HDV-IgG. Based on the gestation duration, the highest seroprevalence of HBsAg was detected in women in their third trimester with 14.4% (16/111)

followed by second trimester 16.1% (9/56) (Table 3). Seroprevalence was not detected in women in their first trimester. There was significant association between the gestational age and HBsAg, HBeAb and HDV-IgG seropositivity ($P = 0.000$).

PCR detection of HBV and HDV

All samples, which tested positive for HBsAg marker only ($n = 25$) were subjected to PCR analysis for the detection of HBV DNA because HDV depends solely on expression of HBV surface antigen (HBsAg) to complete its life cycle (Mentha et al., 2019). Also, those positive for both HBsAg and HDV-IgG ($n = 9$) were subjected to PCR analysis for the detection of HDV RNA. For HBV DNA, a seroprevalence of 12% (3/25) was detected. The highest seroprevalence was detected in third trimester (12%; $n = 3/25$) and age group 16-25 (8%; $n = 2/25$). However, all samples positive for both HBsAg and HDV-IgG tested negative for HDV RNA.

Table 2: Prevalence in relation to age group among pregnant women attending antenatal clinic in LAUTECH.

Age group	Freq (%)	HBsAg (%)	HBeAb (%)	HBcAb (%)	HDV-IgG (%)
16-25	58 (32.2)	10 (5.6)	2 (1.1)	4 (2.2)	4 (2.2)
26-35	104 (57.8)	11 (6.1)	2 (1.1)	3 (1.7)	3 (1.7)
36-45	18 (10.0)	4 (2.2)	1 (0.6)	2 (1.1)	2 (1.1)
X^2		2.544	0.892	2.834	2.948
P-value		0.280	0.640	0.242	0.567

*Pearson chi-square.

Table 3: Distribution of HBV markers and HDV-IgG according to gestational age.

	Seroprevalence n (%)			
	HBsAg	HBeAb	HBcAb	HDV-IgG
1st trimester ($n = 13$)	0	0	0	0
2nd trimester ($n = 56$)	9 (16.1)	3 (5.4)	4 (7.1)	3 (5.4)
3rd trimester ($n = 111$)	16 (14.4)	2 (1.8)	5 (4.5)	6 (5.4)
X^2	1.210	1.108	1.283	2.865
P-value	0.000	0.000	0.527	0.000

Table 4: Validity of initial screening tool using contingency table.

Method	P-value	Relative risk	OR ¹ (CI)*	Sensitivity	Specificity	Positive predictive value	Negative predictive value	Likelihood ratio
RDT	0.0024	-	48.38 (2.42-968.5)	1.00	0.88	0.12	1.00	8.05
ELISA	0.0004	4.33	57.00 (2.59-125.0)	0.75	1.00	1.00	0.77	-

¹Odd ratio *Confidence interval.

In this study, HBV markers and HDV-IgG seroprevalence was analysed in pregnant women. The overall prevalence of HBV among pregnant women attending LAUTECH teaching hospital antenatal clinic was found to be 13.9% (25/180), of which 1.7% (3/25) corresponding to 1.6% overall (3/180) were also positive for HBV DNA while that of HDV was found to be 5% (9/180). The prevalence of HBsAg observed in this study is high compared to a report by Sharma *et al.* who reported 10% HBsAg prevalence and in comparison, to previous reports from Africa, like 1.1% in Mali and 6.5% in south eastern Nigeria; but contrarily to Rohtagi *et al.* who have found a higher prevalence (25%) in pregnant women and Stevens *et al.* (1975) who have reported a prevalence of 17% (Munaro and William, 1997; Tounkara *et al.*, 2009; Okeke *et al.*, 2012; Okonkwo *et al.*, 2022). HBsAg prevalence observed in this study indicates endemicity in pregnant women attending LAUTECH antenatal clinic and may possibly be consequence of sexual contact with an infected partner.

Sharma *et al.* (2023) reported that onset of hepatitis in mothers in third trimester of pregnancy show a higher incidence (76%) of transmission to foetal as compared to only 10% in the first and second trimester. This study shows HBsAg incidence of 14.4% and HDV-IgG incidence of 5.4% in third trimester. It also shows a seroprevalence of HBeAb (2.8%) and HBcAb (5%) which indicate that few of the participants are HBV chronic carrier. It has also been reported that a positive HBsAg mother has a 20% risk of transmitting infection to foetus at birth while positive HBeAg mother has a 90% risk of transmitting the infection. Also, transmission of HDV from Mother-To-Child increases with HBV DNA especially in the third trimester of pregnancy (Sharma *et al.*, 2023).

HBV result fall within 5-30 % reported in Maragua, Kenya (Wang *et al.*, 2019) and above the WHO cut-off level of endemicity of 8% (Sreedhar *et al.*, 2015). High prevalence between 8-20% have been reported in many parts of Africa with Nigeria reporting a significant prevalence. For instance, Ndams *et al.* (2008) reported a prevalence of 12.3% in pregnant women in Minna, with the highest rate observed in the middle age group who are more likely sexually active than the younger or older group (Hou *et al.*, 2005; Ndams *et al.*, 2008). Also 8.2% prevalence was reported in pregnant women attending Federal Medical Centre, Yola with the highest rate found

in women in the middle age group (Olokoba *et al.*, 2011). This study also found the highest rate (11.7%) in women in the middle age group (18-35) which implies higher chance of MTCT.

Of the 25 HBsAg positive pregnant women, 36% (9/25) were positive for HDV-IgG corresponding to 5% overall (9/180), of which none were positive for HDV RNA; this indicates possibility of past HDV infections which led to antibody presence without active viral replication or potential role of viral latency. Non-detection of HDV RNA may also be due to sensitivity of the PCR assay for certain genotypes. Studies have reported 4.5% anti-HDV prevalence among HBsAg-positive individuals, 16.4% among those attending hepatology clinics. A meta-analysis reported that prevalence of anti-HDV among HBsAg-positive individual are higher in western and middle Africa (Stockdale *et al.*, 2020). The reported global HDV prevalence is 5%. HDV prevalence data are not much in Nigeria but a 2016 article reported 9% prevalence in South-western Nigeria.

A study in Cross-river Nigeria found that the prevalence of HDV among asymptomatic HBV carriers was 7.3% (n=4/55), with the highest prevalence observed in age group 20-39 (Olokoba *et al.*, 2011). A study in Maiduguri Nigeria found HDV seroprevalence of 3.3% (6/180) among HBsAg-positive individuals which is higher than the global prevalence cut-off (0.82%) (Okonkwo *et al.*, 2022). Very few studies focus on pregnant women who are major route for both horizontal and vertical transmission of HDV and HBV (Ndzie *et al.*, 2024).

HDV infection in pregnancy lead to higher risk of preterm birth, perinatal transmission and liver complications for both mother and baby (viral hepatitis). A study in Cameroon shows that HDV prevalence among HBsAg-positive pregnant women was 32.3% (n= 42/130) which implies an increased risk of liver disease progression leading to more severe outcomes and an increased likelihood of pregnancy-related complications (Ndzie *et al.*, 2024).

The non-existence of HDV (RNA) prevalence in our study indicates a past HDV infection that has been successfully responded to by the immune system or that the virus is not currently active or replicating in the body (chronic cases). It can also be due to low detection threshold of the PCR assay in comparison

to the HDV ELISA.

Detection of HDV-IgG does not correspond with molecular detection of HDV RNA; we therefore recommend retesting by molecular method.

Conclusions and Recommendations

While HDV infection is still neglected and not routinely diagnosed in pregnant women positive for Hepatitis B virus, the data from this study shows that HDV is of major health concern to pregnant women even though there was no active infection reported in this study, however the study shows that significant number of the pregnant women have being exposed to HDV infection previously. This data also indicates a possible HDV superinfection on chronic hepatitis B and coinfection of both viruses, which can predispose pregnant women to severe hepatic complications and lead to exacerbation of liver diseases. This also indicates a possible vertical transmission from mother to their babies and 70% chance of babies becoming chronic carriers. Therefore, women especially younger ones should be educated about the infection and awareness of this disease should be increased by routine screening of pregnant women to avoid hepatic complications and vertical transmission. Further research is also required to clearly depict the actual burden of HDV infection in pregnant women and in Nigeria.

Study limitations

The limitation of this study was that it was a cross sectional study and the women were not followed up until delivery to know how many actually had chronic HBV infection or how many only had an acute infection. Also, we had no access to their vaccination records and there were cost constraints.

Acknowledgements

We thank the team of HRH-CERID for their technical support during the laboratory work. We also thank the pregnant women and management of LAUTECH teaching hospital, Ogbomosho for their cooperation. Also thanks to Dr Sola Oyekale (LAUTECH) for his guidance during statistical analysis.

Novelty Statement

This study provides an insight into the prevalence of

HDV among HBV-positive pregnant women in Ogbomosho, Nigeria, a topic with limited regional data. By employing a combination of serological and molecular diagnostic method, this research highlights the significant exposure to HDV among this study population despite the absence of active viral replication. The findings underscore the potential risks of vertical transmission, emphasizing the need for routine screening and targeted interventions for pregnant women in Nigeria.

Author's Contribution

Zainab Salami: Conceptualized the study, developed the methodology, performed the experiments, wrote the original draft and performed data analysis.

Opaleye: Contributed in conceptualizing the study, provided resources, directed the experiment, contributed to writing the original draft, participated in reviewing and editing the manuscript and validated the results. **Ojurongbe:** Provided resources and validated the results.

Olowe: Reviewed and edited the manuscript.

Titilayo Olayinka: Performed the experiments and drafting the manuscript.

All authors read and approved the final manuscript.

Ethical approval

This study was approved by LAUTECH teaching hospital ethical review committee (LTH/OGB/EC/2023/380). Informed consent was obtained from each eligible pregnant woman after explaining the scope of the study.

Conflicts of interest

The authors have declared no conflict of interest.

References

- Alavian, S.M., Salehi-Vaziri, M., Sadeghi, F., Almasi, H.A. and Gholami, F.M., 2013. Hepatitis B virus infection in the general population of Iran: An updated systematic review and meta-analysis. *Hepatitis Monthly*, 16(4): e35577. <https://doi.org/10.5812/hepatmon.35577>
- Amponsah-Dacosta, E., 2021. Hepatitis B virus infection and hepatocellular carcinoma in sub-Saharan Africa: Implications for elimination of viral hepatitis by 2030. *World J. Gastroenterol.*, 27(36): 6025-6038. <https://doi.org/10.3748/wjg.v27.i36.6025>

- Andernach, I.E., Leiss, L.V., Tarnagda, Z.S., Tahita, M.C., Otegbayo, J.A., Forbi, J.C., Omilabu, S., Gouandjika-Vasilache, I., Komas, N.P., Mbah, O.P. and Muller, C.P., 2014. Characterization of hepatitis delta virus in sub-Saharan Africa. *J. Clin. Microbiol.*, 52(5): 1629–1636. <https://doi.org/10.1128/JCM.02297-13>
- Caviglia, G.P., Ciancio, A. and Rizzetto, M., 2005. A review of HDV infection. *Viruses*, 14(8): 1749. <https://doi.org/10.3390/v14081749>
- Hou, J., Liu, Z. and Gu, F., 2005. Epidemiology and prevention of hepatitis B virus infection. *Int. J. Med. Sci.*, 2: 50–57. <https://doi.org/10.7150/ijms.2.50>
- Idowu, A., Oluseyi, K., Ayodele, O.A. and Adebawale, F.A., 2019. Seroprevalence and determinants of hepatitis B viral status in pregnant women attending antenatal clinics in an urban community of Oyo state, South-West Nigeria. *Int. J. Commun. Med. Publ. Health*, 6(10): 4139–4144. <https://doi.org/10.18203/2394-6040.ijcmph20194467>
- Jourdain, G., Ngo-Giang-Huong, N. and Khamduang, W., 2019. Current progress in the prevention of mother-to-child transmission of hepatitis B and resulting clinical and programmatic implications. *Infect. Drug Resist.*, 12: 977–987. <https://doi.org/10.2147/IDR.S171695>
- Kyaw, Y.Y., Lwin, A.A., Aye, K.S., Thu, H.M., Htun, M.M., Soe, H.O., Aye, K.T., Thant, K.Z., Hwang, H.J. and Cheong, J., 2020. Distribution of hepatitis B virus genotypes in the general population of Myanmar via nationwide study. *BMC Infect. Dis.*, 20(1): 552. <https://doi.org/10.1186/s12879-020-05269-z>
- Lempp, F.A., Roggenbach, I., Nkongolo, S., Sakin, V., Schlund, F., Schnitzler, P., Wedemeyer, H., Le Gal, F., Gordien, E., Yurdaydin, C. and Urban, S., 2021. A rapid point-of-care test for the serodiagnosis of hepatitis delta virus infection. *Viruses*, 13(12): 2371. <https://doi.org/10.3390/v13122371>
- Lunel-Fabiani, F., Mansour, W., Amar, A.O., Aye, M., Le Gal, F., Malick, F.Z.F., Baïdy, L., Brichler, S., Veillon, P., Ducancelle, A. and Gordien, E., 2013. Impact of hepatitis B and delta virus co-infection on liver disease in Mauritania: A cross-sectional study. *J. Infect.*, 67(5): 448–457. <https://doi.org/10.1016/j.jinf.2013.06.008>
- Mentha, N., Clément, S., Negro, F. and Alfaiate, D., 2019. A review on hepatitis D: From virology to new therapies. *J. Adv. Res.*, 17: 3–15. <https://doi.org/10.1016/j.jare.2019.03.009>
- Munaro, B.H. and William, F., 1997. Statistical methods for health care research. Lippincott Williams & Wilkins: 5th edn. pp. 261–262. Philadelphia, USA.
- Ndams, I.S., Joshua, I.A., Luka, S.A. and Sadiq, H.O., 2008. Epidemiology of Hepatitis B; The infection among pregnant women in Minna, Nigeria. *Sci. World J.*, 3: 5–8. <https://doi.org/10.4314/swj.v3i3.51810>
- Ndzie Ondigui, J.L., Mafopa, G.N., Lobe, C., Wandji, B., Awoumou, P., Voussou, D.P., Peyonga, P., Manju, A.S., Verbe, V., Kamgaing, S.R., Moudourou, S.A., Gutierrez, A., Garcia, R., Fernandez, I., Riwoom, E.S.H., Mbu, R. and Torimiro, J., 2024. Prevalence and risk factors of transmission of hepatitis delta virus in pregnant women in the Center Region of Cameroon. *PLoS One*, 19(6): e0287491. <https://doi.org/10.1371/journal.pone.0287491>
- Okeke, T.C., Obi, S.N., Okezie, O.A., Ugwu, E.O., Akogu, S.P., Ocheni, S. and Ezenyeaku, C.C., 2012. Coinfection with hepatitis B and C viruses among HIV positive pregnant women in Enugu south east, Nigeria. *Niger. J. Med.*, 21(1): 57–60.
- Okonkwo, U.C., Okpara, H.C., Inaku, K., Aluka, T.M., Chukwudike, E.S., Ogarekpe, Y., Emin, E.J., Hodo, O. and Otu, A.A., 2022. Prevalence and risk factors of Hepatitis D virus antibody among asymptomatic carriers of Hepatitis B virus: A community survey. *Afr. Health Sci.*, 22(1): 504–510. <https://doi.org/10.4314/ahs.v22i1.59>
- Olokoba, A.B., Salawu, F.K., Danburam, A., Olokoba, L.B., Midala, J.K., Badung, L.H. and Olatinwo, A., 2011. Hepatitis B virus infection amongst pregnant women in North-eastern Nigeria – a call for action. *Niger. J. Clin. Pract.*, 14: 10–13. <https://doi.org/10.4103/1119-3077.79232>
- Oluremi, A.S., Opaleye, O.O., Ogbolu, D.O., Alli, O.A.T., Omolade, A., Olubunmi A., Ogunleke, O.A., Ayodele, O., Bello, M.D., Enitan, S.S., Adediji, I.O., Adelakun, A.A. and Ibrahim, E.S., 2020. High viral hepatitis infection among pregnant women attending antenatal clinic in Adeoyo Maternity Teaching Hospital Ibadan (AMTHI) Oyo State, Nigeria. *J. Immun. Immunochem.*, 41(5): 913–923. <https://doi.org/10.1016/j.jim.2020.05.008>

/10.1080/15321819.2020.1807358

- Opaleye, O.O., Japhet, O.M., Adewumi, O.M., Omoruyi, E.C., Akanbi, O.A., Oluremi, A.S., Wang, B., Tong, H.V., Velavan, T.P. and Bock, C.T., 2016. Molecular epidemiology of hepatitis D virus circulating in Southwestern Nigeria. *Virol. J.*, 13: 61. <https://doi.org/10.1186/s12985-016-0514-6>
- Ramachandran, K., Agarwal, R., Sharma, M.K., Bhatia, V. and Gupta, E., 2020. Prevalence of Hepatitis Delta Virus Infection among Hepatitis B Virus-Infected and Exposed Patients. *J. Glob. Infect. Dis.*, 12(4): 197–201. https://doi.org/10.4103/jgid.jgid_137_19
- Sagnelli, C., Sagnelli, E., Russo, A., Pisaturo, M., Occhiello, L. and Coppola, N., 2021. HBV/HDV co-infection: Epidemiological and clinical changes, recent knowledge and future challenges. *Life (Basel, Switzerland)*, 11(2): 169. <https://doi.org/10.3390/life11020169>
- Sausen, D.G., Shechter, O., Bietsch, W., Shi, Z., Miller, S.M., Gallo, E.S., Dahari, H. and Borenstein, R., 2022. Hepatitis B and Hepatitis D Viruses: A comprehensive update with an immunological focus. *Int. J. Mol. Sci.*, 23(24): 15973. <https://doi.org/10.3390/ijms232415973>
- Sharma, M.K., Gupta, E., Bhugra, A., Samal, J., Khodare, A., Singh, K. and Rastogi, A., 2023. Performance evaluation of an improved HBsAg assay (HBsAg NEXT) for the detection of HBsAg levels. *J. Lab. Phys.*, 15(4): 533–538. <https://doi.org/10.1055/s-0043-1768633>
- Sirilert, S. and Tongsong, T., 2021. Hepatitis B virus infection in pregnancy: Immunological response, natural course and pregnancy outcomes. *J. Clin. Med.*, 10(10): 2926. <https://doi.org/10.3390/jcm10132926>
- Sreedhar, K., Suresh, B., Sindhuja, K. and Anitha, M., 2015. Association of ABO and Rh blood groups to HBV, HCV infections among blood donors in a blood bank of tertiary care teaching hospital in Southern India: A retrospective study. *Int. J. Res. Med. Sci.*, 3: 1672–1676. <https://doi.org/10.18203/2320-6012.ijrms20150249>
- Stevens, C.E., Bcaaley, R.P., Tsiri, J. and Lee, W.C., 1975. Vertical transmission of hepatitis B antigen in Taiwan. *N. Eng. J. Med.*, 292: 771–774. <https://doi.org/10.1056/NEJM197504102921503>
- Stockdale, A.J., Kreuels, B., Henrion, M.Y.R., Giorgi, E., Kyomuhangi, I., De Martel, C. and Thursz, M., 2020. The global prevalence of hepatitis D virus infection: Systematic review and meta-analysis. *J. Hepatol.*, 73(3): 523–532. <https://doi.org/10.1016/j.jhep.2020.04.008>
- Tounkara, A., Sarro, Y.S., Kristensen, S., Dao, S., Diallo, H., Diarra, B., Noumsi, T.G. and Guindo, O., 2009. Seroprevalence of HIV/ HBV coinfection in Malian blood donors. *J. Int. Assoc. Phys., AIDS Care*, 8(1): 47–51. <https://doi.org/10.1177/1545109708330118>
- Wang, D.D., Yi, L.Z., Wu, L.N., Yang, Z.Q., Hao, H.Y., Shi, X.H., Wang, B., Feng, S.Y., Feng, Y.L. and Wang, S.P., 2019. Relationship between maternal PBMC HBV cccDNA and HBV serological markers and its effect on HBV intrauterine transmission. *Biomed. Environ. Sci.*, 32(5): 315–323.
- World Health Organization, 2024. Global hepatitis report 2017. WHO: Geneva, Switzerland. <https://www.who.int/hepatitis/publications/global-hepatitis-report2017/en/> (accessed 24 Aug 2024).