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Abnormal Umbilical Doppler: Incidence and Neonatal Outcomes among Hypertensive Disorders in Pregnancy at KCMC: A Hospital-Based Prospective Cohort Study

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Abstract

Hypertensive disorders of pregnancy (HDP) are the most common maternal and perinatal health challenges. Globally, the incidence of HDP increased from 16.30 million to 18.08 million, with a total increase of about 10.9% from 1990 to 2019. Umbilical Doppler study in hypertensive disorders of pregnancy helps to predict neonatal outcomes and prevent neonatal and maternal morbidity and mortality. **Objective:** This study aims to determine the incidence of abnormal umbilical Doppler among hypertensive pregnant women, to identify the adverse neonatal outcomes associated with abnormal umbilical Doppler, and also to detect the diagnostic predictive values of umbilical Doppler to neonatal outcomes at KCMC. **Material and methods:** A hospital-based prospective cohort study included women with hypertensive disorders of pregnancy from the gestational age of 28 weeks and above, followed up to delivery during the study period from August 2022 to March 2023. Multivariate logistic regression analysis was used to determine the association between AUD and neonatal outcomes. **Results**: Out of 112 women with HDP, the incidence of abnormal umbilical Doppler was 38 (33.93%). Abnormal umbilical Doppler was associated with neonates with low birth weight aOR (95% of CI) of 4.52 (1.59 - 12.83) p = 0.005 and neonatal ICU admission 9.71 (2.90 - 32.43) p < 0.001, the sensitivity of abnormal umbilical Doppler to low birth weight was 61.90% and that of ICU admission was 72.20%. **Conclusion:** The incidence of abnormal umbilical Doppler is high in hypertensive disorders of pregnancy which is associated with an increase in neonatal low birth weight

and neonatal ICU admissions, the sensitivity of abnormal umbilical Doppler in prediction of low birth weight and neonatal ICU admission is significant hence the routine use of umbilical Doppler assessment among hypertensive pregnant women is crucial.

Keywords

Hypertensive Disorders in Pregnancy, Umbilical Doppler, Neonatal Outcomes, KCMC

1. Background

Hypertensive disorders of pregnancy (HDP) are the most common maternal and perinatal health challenges. They can be classified as pre-existent or induced by the pregnancy or both [1]. Globally, the incidence of HDP increased from 16.30 million to 18.08 million, with a total increase of about 10.9% from 1990 to 2019. The highest incidence of HDP in 2019 was reported in South Asia to be 3.84 million, in western sub-Saharan Africa 3.71 million, and in eastern sub-Saharan Africa 3.12 million [2].

Substantially Hypertensive disorders in pregnancy increase the high risk of complications and contribute to maternal and perinatal morbidity and mortality [3]. Perinatal mortality due to HDP is about three to five times higher as compared to those without the disorders worldwide [4]. Other HDP-related perinatal and neonatal complications include preterm birth, FGR, oligohydramnios, placenta abruption, fetal hypoxia, non-reassuring fetal status, and perinatal death [5]. To reduce these serious complications, there is a need to predict their related risks which may help to improve care by providing appropriate antenatal surveillance and therapeutic interventions for which umbilical artery Doppler plays a big role.

Umbilical artery Doppler assessment is used in the clinical evaluation of high-risk pregnancies including HDP, it is a non-invasive and safe method of studying blood flow characteristics in both the fetoplacental and uteroplacental circulations [5]. It is one of the most useful tools for predictions of the perinatal outcome [6]. Either, the umbilical artery Doppler is the potential tool for uteroplacental surveillance of high-risk pregnancies including HDP, it is reliable in detecting early fetoplacental compromise in hypertensive pregnant women and is a useful tool for the decision and appropriate timing of intervention for delivery in reducing perinatal morbidity and mortality. The use of Doppler ultrasound of the umbilical artery in managing high risk pregnancies has been reported as can reduce perinatal deaths by 38% [7].

Nevertheless, HDP particularly pregnancy-induced hypertension (PIH) remains an unsolved problem in both high, middle, and low-income countries; and this is associated with high maternal and perinatal morbidity and mortality worldwide [5].

Observational studies have clearly shown the association between abnormal umbilical artery Doppler waveforms and adverse pregnancy outcomes such as fetal asphyxia and perinatal mortality. However, there is insufficient data from lower- and middle-income countries on the observed associations, and therefore, further research is required.

In Tanzania, many perinatal deaths are unexplained intrauterine deaths. The majority of the women attending ANC are clinically healthy hence the major goal of this study was to improve the management of HDP and address future early interventions to reduce and control the risk of adverse neonatal outcomes (morbidity and mortality) using umbilical artery Doppler assessment.

2. Methods

2.1. Study Design and Area

This was a hospital-based prospective cohort study to investigate the abnormal umbilical Doppler: incidence and neonatal outcomes along with the diagnostic efficacy of umbilical Doppler among women with hypertensive disorders in pregnancy at KCMC-zonal referral hospital in the northern part of Tanzania between August 2022 to March 2023. The AUD was detected by screening hypertensive pregnant women who attended ANC at the obstetrics/gynecology clinic and those admitted to the maternity ward through the labor ward at KCMC. Umbilical artery Doppler indices were RI, PI, and S/D and they were considered abnormal if their values were above the 95th percentile of the respective gestation age. This design was appropriate to determine the incidence of AUD and the neonatal outcome among women with HDP in the specified study frame in a given period.

This study was conducted at KCMC zonal consultancy referral hospital, located at Moshi municipal council in Northern Tanzania. The site was purposively selected because of having screening capacity, and the number of women who attended ANC and those admitted for obstetrics care was high per day which was a good site for this study. Knowing that this is the zonal consultancy referral hospital with an average of 3000 women admitted per month, and about half of these women were referred from other facilities for which the majority of them presented with a high risk of pregnancy-related complications including HDP, so the hypertensive disorders cases could be easily reached.

2.2. Study Population

Women with hypertensive disorders in pregnancy attended ANC and those admitted in the maternity ward through the labor ward at KCMC hospital in Obstetrics and Gynecology department during the study period.

2.3. Study Settings

This was a hospital-based prospective cohort study to investigate the abnormal umbilical Doppler: incidence and neonatal outcomes along with the diagnostic

efficacy of umbilical Doppler among women with hypertensive disorders in pregnancy at KCMC-zonal referral hospital in the northern part of Tanzania between August 2022 to March 2023. The AUD was detected by screening pregnant women who attended ANC at the obstetrics/gynecology clinic and those admitted to the maternity ward through the labor ward at KCMC as shown in **Appendix I**. Umbilical artery Doppler indices were RI, PI, and S/D and they were considered abnormal if their values were above the 95th percentile of the respective gestation age. This design was appropriate to determine the incidence of AUD and the neonatal outcome among women with HDP in the specified study frame in a given period.

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2.4. Statistical Methods

All statistical calculations were coded and entered using the statistical package SPSS (Statistical Package for the Social Sciences) version 25 and Stata 17.

Data were statistically described in terms of mean, standard deviation (± SD), median, and range for qualitative data or frequencies (number of cases) and percentages for categorical data.

Comparison of numerical variables between the study groups was done using the student *t*-test for independent samples when normally distributed and the Mann-Whitney *U* test for independent samples when not normally distributed.

For comparing categorical data, Chi-square (χ^2) test was performed. When the expected frequency is <5, Fisher's exact test was used instead.

The test of sensitivity, specificity, and positive and negative predictive values (PPV and NPV) was used.

Multivariate logistic regression analysis was used to determine the association between AUD and neonatal outcomes.

For all tests, P values less than 0.05 was considered statistically significant.

2.5. Ethical Approval

Ethical approval to conduct this study no **PG106/2022** was obtained from KCMU College and Research Ethics Review Committee. Permission to carry out this study was obtained from the Executive Director of the KCMC together with Head of the obstetrics and gynecology and radiology departments. Written and verbal informed consent were obtained from the study participants. Participants were given unique identification numbers to ensure privacy and confidentiality.

3. Results

3.1. Enrolment of the Study Participants

During the study period from August 2022 to March 2023, there were a total of 119 enrolled hypertensive pregnant women. We excluded 3 (2.52%) women who lost follow-up, 3 (2.50%) with critical conditions who were admitted to ICU and could not be taken to the radiology department for Doppler assessment, 1 (0.88%) who missed some of the Doppler indices the remaining 112 were included in the analysis as shown in Figure 1.

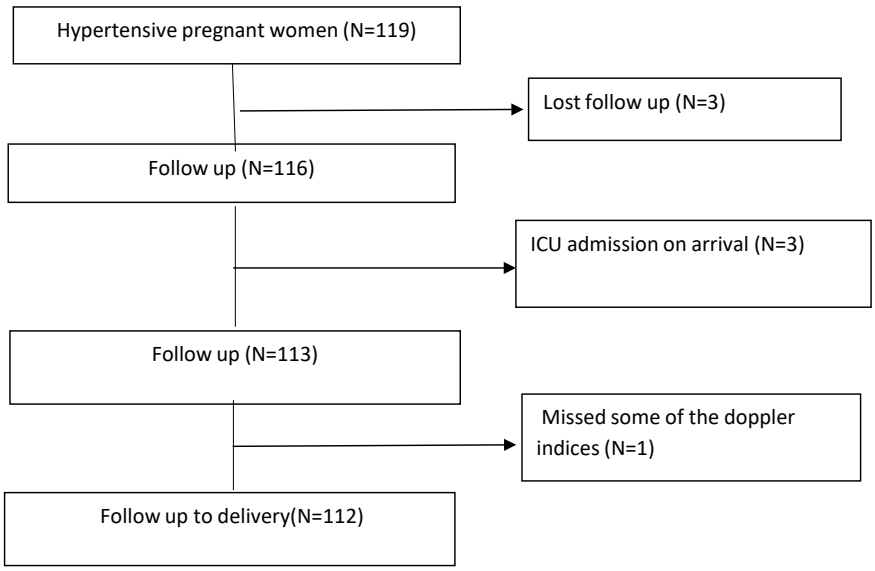

Figure 1. Flow chart of the study participants.

3.2. Social Demographic Characteristics

Most of the patients were aged 31years and above 50 (44.64%) 16 (32.00%) presented with abnormal umbilical Doppler while 34 (68.00%) presented with normal umbilical Doppler study, the least patients were of age less than 20 years 13 (11.61%) and the mean age was (Mean ± SD) (29.16 ± 6.248) as shown in Table 1.

Table 1. Social demographic characteristics.

Patient Characteristics	n (%)	Doppler findings	
		Normal Umbilical Doppler (%)	Abnormal Umbilical Doppler (%)
	112	**74 (66.07)**	**38 (33.93)**
Age group (Mean ±SD) (29.16 ± 6.248)			
<20	13 (11.61)	8 (61.54)	5 (38.46)
21 - 30	49 (43.75)	32 (65.31)	17 (34.69)
≥31	50 (44.64)	34 (68.00)	16 (32.00)

Continued

Residence			
Rural	29 (25.89)	21 (72.41)	8 (27.59)
Urban	83 (74.11)	53 (63.86)	30 (36.14)
Marital status			
Married	90 (80.36)	59 (65.56)	31 (34.44)
Single	22 (19.64)	15 (68.18)	7 (31.82)
Occupation			
House wife	78 (69.64)	55 (70.51)	23 (29.49)
Farmer	16 (14.29)	6 (37.50)	10 (62.50)
Service business	18 (16.07)	13 (72.22)	5 (27.78)
Education level			
Primary	5 (4.46)	4 (80.00)	1 (20.00)
Secondary	101 (90.18)	67 (66.34)	34 (33.66)
Higher	6 (5.36)	3 (50.00)	3 (50.00)

3.3. Umbilical Doppler Characteristics

The overall incidence of abnormal umbilical Doppler among 112 participants was 38 (33.93%) while that of normal umbilical Doppler was 74 (66.07%) in which the characteristics of indices were higher with abnormal RI 37 (33.04%), followed by abnormal PI and S/D both 31 (27.68%) each and the least being the absence of EDF 8 (7.14%) (see Table 2).

Table 2. Umbilical Doppler characteristics.

Variable	n (%)	Normal	Abnormal
		Umbilical Doppler (%)	Umbilical Doppler (%)
	112	**74 (66.07)**	**38 (33.93)**
No EDF			
Yes	8 (7.14)	0 (0.00)	8 (100.00)
No	104 (92.86)	74 (74.15)	30 (28.85)
PI			
Normal	81 (72.32)	74 (91.36)	7 (8.64)
Abnormal	31 (27.68)	0 (0.00)	31 (100.00)
RI			
Normal	75 (66.96)	74 (98.67)	1 (1.33)
Abnormal	37 (33.04)	0 (0.00)	37 (100.00)
S/D			
Normal	81 (72.32)	74 (91.36)	7 (8.64)
Abnormal	31 (27.68)	0 (0.00)	31 (100.00)

EDF-end diastolic flow; **PI**-pulsitility index; **RI**-resistive index; **S/D**-systole/diastole ratio.

Low birth weight was in 21 (18.75%) of which 13 (61.90%) were from women with abnormal umbilical Doppler and only 8 (38.10%) had normal umbilical Doppler.

Among 112 patients only 8 (7.14%) delivered neonates with low Apgar scores of less than 7 in 5th minute for which 4 (3.57%) were from the group of abnormal umbilical Doppler study.

Neonatal ICU admission was found to be 18 (16.07%) of which 13 (72.22%) were neonates from women with abnormal umbilical Doppler findings and only 5 (27.78%) were from the control group.

Early neonatal death was in 6 (5.36%) for which only 2 (33.33%) out of 4 (66.67%) were from women with abnormal umbilical Doppler.

3.4. Association between AUD and Neonatal Outcomes

The group with abnormal umbilical artery Doppler had a 4.29 times probability of getting neonates of low birth weight compared to the normal Doppler group. After adjusting for other variables, the adjusted odds ratio (aOR) remained the same at 4.52. The crude odds ratio (cOR) and adjusted odds ratio (aOR) were statistically significant with p values of 0.004 and 0.005, respectively. This suggests that abnormal umbilical artery Doppler measurements are independently associated with an increased risk of low birth weight, even after accounting for other variables.

There was no significant difference in the probability of having a low Apgar score between the abnormal Doppler group and the normal Doppler group. The crude odds ratio (cOR) and adjusted odds ratio (aOR) were not statistically significant. This suggests that Doppler measurements of the umbilical artery are not associated with an increased risk of low Apgar scores.

There was no significant association between umbilical artery Doppler measurements and neonatal death. The crude odds ratio (cOR) and adjusted odds ratio (aOR) were not statistically significant.

The group with abnormal umbilical artery Doppler was 7.18 times more likely to be admitted to the ICU compared to the normal Doppler group. After adjustment for other variables, the adjusted odds ratio (aOR) increased to 9.71, indicating a strong association. The crude odds ratio (cOR) and adjusted odds ratio (aOR) were statistically significant with p values of 0.001 and 0.000 respectively as shown in **Table 3**.

3.5. Predicting Values of Abnormal Umbilical Doppler with Adverse Neonatal Outcomes

From this study we found 61.90% of cases with low birth weight are correctly identified based on the abnormal Doppler findings and 72.50% of cases without low birth weight are correctly identified based on normal Doppler findings.

72.2% of cases with ICU admission are correctly identified based on the abnormal Doppler findings and 73.4% of cases without ICU admission are correctly identified based on normal Doppler findings (see **Table 4**).

Table 3. Multivariate logistic regression analysis for the association between AUD and neonatal outcomes.

Variable	Umbilical artery Doppler	Umbilical artery Doppler	cOR (95% of CI)	P-Value	aOR (95% of CI)	P-Value
Low birth weight	8 (38.10)	13 (61.90)	4.29 (1.59 - 11.59)	**0.004**	4.52 (1.59 - 12.83)	**0.005**
Low Apgar score	4 (50.00)	4 (50.00)	2.06 (0.49 - 8.73)	**0.327**	2.50 (0.54 - 11.54)	**0.257**
Neonatal death	4 (66.67)	3 (33.33)	0.97 (0.17 - 5.56)	**0.975**	1.25 (0.20 - 7.23)	**0.812**
ICU admission (yes)	5 (27.78)	13 (72.22)	7.18 (2.32 - 12.18)	**0.001**	9.71 (2.90 - 32.43)	**< 0.001**

cOR = crude odds ratio, aOR = adjusted odds ratio P value = probability value CI = confidence interval. The neonatal outcomes were adjusted for use of steroids, smoking, parity and alcohol consumption.

Table 4. Predicting values of abnormal umbilical Doppler with adverse neonatal outcomes.

Neonatal outcomes	Sensitivity	Specificity	PPV	NPV
Low birth weight	61.90%	72.50%	34.20%	89.20%
Low Apgar score	50%	67.30%	10.50%	96.40%
Small for gestation age	61.90%	72.50%	34.20%	89.20%
Neonate status	33.30%	66%	5.20%	94.6
ICU admission	72.20%	73.40%	34.20%	93.20%

4. Discussion

We found there is high incidence of abnormal umbilical Doppler among women with hypertensive disorders of pregnancy, increased rate of low birth weights and neonatal ICU admissions, also we found high sensitivity of abnormal umbilical Doppler in predicting low birth weights and neonatal ICU admissions.

After the last umbilical Doppler evaluation of 112 patients with hypertensive disorders of pregnancy, we found the high incidence of abnormal umbilical Doppler similarly to other study by Yadav *et al.*, and Subramanian *et al.* [5] [8], this is because we used nearly the same sample size and most were of the same methodology.

We found abnormal umbilical Doppler was statistically associated with increase chances of low birth weights and neonatal ICU admissions which was also found to be the same with other studies by Yadav *et al.* [5], this is biologically explained by uteroplacental insufficiency resulted by vasculopathy from the long standing effect of hypertensive disorders of pregnancy, hence most likely by the time there are significant changes of umbilical Doppler flow the fetus has already started to sustained insufficient blood supply enough to affect the weight gain, Again with the low birth weight increases neonatal morbidity which might be the explanation for increase ICU admissions.

In this study we found abnormal umbilical Doppler has high adverse neonatal outcomes predictive values similarly to the observations from studies by El-Demiry *et al.* and Moawad [9], E.M.I *et al.* [10] because they all involved qualified radiologists and obstetricians in studying and evaluating the umbilical Doppler indices.

5. Limitations of the Study

The study did not meet the desired sample size of 140 and ended up with 112 in this study period.

KCMC being a consultant hospital is considered to be receiving critical patients with high morbidity which might not be a good representative of the general population.

6. Conclusions

The incidence of abnormal umbilical Doppler is high among women with hypertensive disorders of pregnancy.

Abnormal umbilical Doppler is highly associated with low birth weight and neonatal ICU admission.

There is a significantly high predictive value of abnormal umbilical Doppler to low birth weight and neonatal ICU admission.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Abbreviations

AUD	Abnormal Umbilical Doppler
EDF	End diastolic flow
HDP	Hypertensive disorders in pregnancy
IQR	Interquartile range
KCMUCo	Kilimanjaro Christian Medical University College
NICU	Neonatal Intensive Care Unit
NPV	Negative predictive value
PIH	Pregnancy-induced hypertension
PI	Pulsatility Index
PPV	Positive predictive value
RI	Resistive Index
SD	Standard deviation
S/D	peak systole/end diastole ratio
Se	Sensitivity
Sp	Specificity
SSA	Sub-Saharan Africa
WHO	World Health Organization

Appendices

Appendix I. Consent Form

PID: ……

Greetings! Yusuph Mwidibo, a student of Kilimajar Christian Medical University College, conducting research entitled **"Abnormal umbilical Doppler: incidence and neonatal outcomes among hypertensive disorders in pregnancy at KCMC-Ahospital based prospective cohort study.".**

Purpose of the study: The purpose of this observational study is to determine the incidence and neonatal outcomes of abnormal umbilical Doppler in hypertensive disorders in pregnancy.

What participation involves

If you agree to participate in this study, you will be required to answer questions about Nutrition assessment and associated factors. Do not hesitate because in this assessment there are no **RIGHT** or **WRONG** answers. You can stop involving yourself in this study at any time, even if you have already given your consent. Refusal to participate or withdrawal from the study will not involve penalty or loss of your role in the facility.

Confidentiality You are strongly assured of the confidentiality of the information collected from you and that it will only be used for the purpose of this study and anonymity will highly be observed when collecting data and compiling reports. All of the information that you provide for the study will be kept completely confidential. We record your responses, but the questionnaire will not have your name on it, and your responses to our questions are identified only by a number, never by name.

Risks: No anticipated risk or harm that may result from participating in this study.

Right of participation in the study: Your participation is absolutely voluntary and there is no penalty for refusing to participate.

Benefits: Although there are no direct benefits to you from participating in this survey, we hope that the survey will help to come up with interventions that will be useful for reducing the effects of morbidity and serious harm related to hypertensive disorders of pregnancy.

Contact Person: If you have questions or concerns after we are finished, you may contact the principal investigator via email: mwidiboy@gmail.com; or mobile: **+255 759 798 267**

Kindly provide us with your consent. If you agree to participate in this study, please sign this consent form. I have read and understood the contents of this form and I have been given a satisfactory explanation with all my questions answered. I therefore consent to participate in this study.

Signature of the participant …… Date……

Signature of research assistant…… Date ……

Appendix II. Data Abstraction Sheet (Questionnaire)

1.0 DEMOGRAPHIC AND OBSTETRIC HISTORY

1.1 Age of the participant (years): _____

1.2 Current residence: ☐ Rural ☐Urban ☐Semi urban

1.3 Marital Status: ☐ Married ☐ Single ☐ Widowed ☐ Divorced

1.4 Occupation: ☐ Housewife ☐ Farmer ☐ Service business ☐ others

1.5 Education level: ☐ None ☐ Secondary ☐ Primary ☐ Higher

1.6 Referred patient: ☐ Yes ☐ No

If Yes: Referred from: ☐ Home ☐ District hospital ☐ regional hospital

1.7 Referred during labor: ☐ Admitted in labor ☐ Admitted before ☐ labor

1.8 Alcohol consumption: ☐ Yes ☐ No

1.9 Smoker: ☐ Yes ☐ No

1.10 Physical activity during pregnancies: ☐ Yes ☐ No

1.11 Number of antenatal visits: _____

1.12 History of abortion: _____

1.13 Number of births/pregnancies: _____

1.14 Number births (parity): _____

1.15 Number of live children: _____

1.16 MUAC: _____

1.17. list of medications used during this pregnancy……

1.18. umbilical artery Doppler indices with its corresponding gestational age……..

1.19. interpretation of each umbilical artery Doppler index whether normal/abnormal…….

2.0 OBSTETRIC EXAMINATION

2.1 Gestation age at admission (wks): _____

2.2. BP (mmHg): _____

2.3 urine Dipstick: _____

2.4 Urine color: _____

2.5 Albumin deposits: _____

2.6 Hemoglobin: _____

2.7 Blood urea: _____

2.8 sugar: _____

2.9 serum createnine: _____

2.10 Complaints during admission (put a tick if applied):

- ☐ Headache
- ☐ Epigastria pain
- ☐ Blurred vision
- ☐ Convulsions
- ☐ Other: _____

2.11 Blood pressure during pregnancy (if any): _____ (mmHg)

2.12 Proteinuria: _____

2.13 Diseases and complications during present pregnancy

_____

_____

3.0 DOPPLER AND OTHER CLINICAL INVESTIGATIONS

3.1 Fetal distress: _____

3.2 Fetal heart rate during labor: _____

DOPPLER ASSESSMENTS

3.3 Umbilical artery Doppler: _____

- ☐ UmA-RI ……. N/A
- ☐ UmA-PI ……. N/A
- ☐ UmA-S/D……. N/A

3.4 Doppler ultrasound of umbilical artery

- ☐ Abnormal
- ☐ Normal

4.0 NEONATAL OUTCOME

4.1 Mode of delivery

- ☐ C/S delivery
- ☐ Spontaneous
- ☐ Assisted

4.2 Birth weight of the baby delivered: _____

4.3 Apgar score: _____

4.4 Small for gestational age

- ☐ Yes
- ☐ No

4.5 Neonate status

- ☐ Alive

- Died
- Stillbirth
- During birth
- Immediate postdelivery

4.6 If born alive, admission to ICU

- Yes
- No

4.7 Any other complications during child birth:

4.8 Other neonatal outcome: _____