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Sonographic Evaluation of Maternal Blood Loss After Childbirth Using Postpartum Inferior Vena Cava Diameter Among Parturients in Kano Metropolis, Nigeria

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Abstract

Postpartum hemorrhage has been a major cause of maternal morbidity and mortality globally every year. Sonographic measurement of inferior vena cava diameter is a cheap, safe, non-invasive method and an indicator of blood loss after childbirth. The study was aimed to establish normal range values of postpartum inferior vena cava (IVC) among parturients in Kano metropolis, Nigeria. A prospective and longitudinal study from September, 2021 to September, 2022 was adopted and a minimum sample size of 210 measurements of IVC intraluminal diameter was calculated for the study using G Power sample size software. The sample comprised of two sets measurements obtained from 105 parturients before delivery and after delivery. The maternal heart rate and systolic blood pressure were measured. Blood samples from all subjects were collected. The data was analyzed using IBM Statistical Software. The range value of IVC diameter on inspiration of the subjects before childbirth was 13.2 mm – 20.3 mm, after childbirth was 9.1 mm – 16.7 mm. The IVC diameter range on expiration before childbirth was 17.3 mm – 24.8 mm, after childbirth was 12.6 mm – 21.4 mm. The Packed Cell Volume (PCV) range of the subjects before childbirth was 35% – 40%, after childbirth was 18% – 33%. The heart rate before childbirth was 64 bpm – 100 bpm, after childbirth was 70 bpm – 100 bpm. The systolic blood pressure before childbirth was 110 mmHg – 120 mmHg, after childbirth was 90 mmHg – 120 mmHg. The shock index before childbirth was 0.5 – 0.9 and after childbirth was 0.6 – 0.9. A statistical significant ($p<0.001$) difference in IVC was observed. Furthermore, a statistical significant ($p<0.001$) difference was obtained in PCV, maternal heart rate, systolic blood pressure and shock index. There was a statistical significant strong positive correlation between IVC and PCV during inspiration and expiration before and after childbirth.

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Keywords: Inferior vena cava, Packed cell volume, Parturient, Postpartum hemorrhage, Sonography

INTRODUCTION

Postpartum hemorrhage (PPH) has been a major cause of maternal morbidity and mortality globally every year (Knight *et al*., 2009). It is broadly defined as maternal blood loss of 500mL (Edhi *et al*., 2013) and up to 1000mL after vaginal and cesarean deliveries respectively (Rath, 2011).Risk factors for PPH are likely linked to the cause of the hemorrhage. It was reported that the main cause is uterine atony followed by trauma, placental abnormalities and coagulopathy (Edhi *et al.*, 2013). PPH is classified based on duration of bleeding time into: primary, occurring within 24hours of birth or secondary, occurring up to 12weeks postpartum (Rath, 2011). The prevalence of PPH differs by assessment method. It accounts for 25 - 43% of maternal death of an estimated 100,000 women worldwide yearly (Nigussie *et al*., 2022). The exact incidence of PPH is difficult to determine due to the difficulty in accurately measuring the blood loses (Ajenifuja *et al*., 2010) but was found to be 2.48% in Nigeria (Garba *et al*., 2019).Signs and symptoms of PPH include increased heart rate, feeling fainting upstanding and increased breath rate (Lynch, 2006). Active management in the last stage of labour with uretonic agent encouraging uterine contraction and has shown to reduce incidence of moderate PPH (Mclintock and James, 20011).Ultrasound is a real-time, non-invasive, rapid, available and cheaper technique to evaluate the size of the inferior vena cava and the patient is not exposed to ionizing radiation (Sidi and Sani, 2021). Sonographic evaluation of the IVC diameter provides rapid non-invasive assessment of a patient's hemodynamic status especially in critically ill patient (Jianjun *et al*., 2018; Dambatta, 2016). Curvilinear probe of frequency ranging from 3.5 to 5.0MHz provide better penetration and visualization of IVC (Goldflam *et al*., 2011). Measurements are mostly made at 2.0cm in a subcostal long axis view while patient is supine. The diameter for the passive expiration and inspiration are assessed to get the maximum and minimum IVC diameter caused by negative intrathoracic pressure inspiration (Oba *et al*., 2018). The increase prevalence of PPH in sub-Saharan region motivated us to conduct a study regarding this concept. This study was aimed to establish normal range value of postpartum inferior vena cava to enable evaluate severity of maternal blood loss in Kano metropolis, Nigeria.

METHODOLOGY

Study Design

A prospective and longitudinal study spanning from September, 2021 to September, 2022 was conducted at Kano Metropolis.

Study Population

The study enrolled 105 pregnant women who transvaginally delivered singleton.

Sample Size

A minimum sample size of 210 measurements of IVC intraluminal diameter was calculated for the study using G Power sample size software as shown below. The sample comprised of two sets measurements obtained from 105 parturients before delivery and after delivery. A moderate effect size (change in IVC diameter between pre and post-delivery measurements) was assumed. The sample size was obtained using the method below:

Tests **-** Means: Difference between two independent means (two groups)

Analysis: A priori: Compute required sample size

Input Tail(s)	=	Two
Effect size d	=	0.5
α err prob	=	0.05
Power (1-β err prob)	=	0.95
Allocation ratio N2/N1	=	1
Output: Non-centrality parameter δ	=	3.6228442
Critical t	=	1.9714347
Df	=	208
Sample size group 1	=	105
Sample size group 2	=	105
Total sample size	=	210
Actual power	=	0.9501287

Sample Method
Simple random sampling method was employed in the selection of the subjects.

Subject Selection Criteria
The subjects were selected among all pregnant women in the maternity clinic that would possibly deliver within twenty four hours in the same clinic.

Inclusive Criteria
The inclusive criteria were women over the age of 16, single pregnancy, parturient and vaginal birth.

Exclusive Criteria
Subjects with antepartum hemorrhage, diabetics and related diseases of the heart, liver and kidneys were excluded.

Ethical Considerations
Ethical clearance to conduct the study was obtained from the Human Right Research and Ethics Committee of the Hospital Management Board Ministry of Health, Kano complying with Helsinki Declaration regarding conduct of research ethics involving human subjects. Informed consent was also obtained from all subjects and were assured of confidentiality.

Data Collection Instrument
A digital portable ultrasound scanner; model ATNL/51353A equipped with 3.5 MHz curvilinear probe was used to obtain sonographic data and maternal heart rate. Blood samples were collected and tested using Parked Cell Volume (PCV). Systolic blood pressure was measured using combination of stethoscope and sphygmomanometer. In obtaining the sonographic measurement of the IVC diameter, the patient was positioned supine on couch and head rested on pillow with the sonographer on the right side of the patient. Ultrasound gel was then applied on the sub-xiphoid epigastric region and right flank of the patient. A 3.5 MHz curvilinear probe was placed longitudinally on the sub-xiphoid area to view the IVC draining into the right atrium. The probe was rotated 90 degrees clockwise to view the IVC properly avoiding confusion with aorta. The maximum diameter was then measured from inner borders of the vessel 2 cm caudal to the right atrium junction during inspiration as shown in Figure 1 and expiration as shown in Figure 2.

Figure 1: IVC diameter during inspiration after childbirth

Figure 1 above demonstrates the IVC inspiration diameter of 0.82 cm measured along the vessel at about a distance of 2.02 cm away from the right atrium junction after childbirth.

Figure 2: IVC diameter during expiration after childbirth

Figure 2 above shows the IVC expiration diameter of 1.09 cm measured along the vessel at a distance of 2.04 cm away from the right atrium junction after childbirth.

Data Analysis

Both descriptive and inferential statistics were used to analyze the data. The range of postpartum IVC diameter during inspiration (IVCi) and expiration (IVCe) within 24 hours before and after childbirth was determined using descriptive statistics. Correlation analysis was used to correlate maternal blood loss with postpartum IVC diameter. The data was analyzed using IBM Statistical Software version 29.0.1.0. Statistical significance was considered at $p < 0.05$.

RESULTS

Table 1: The age, parity and gestational age of the selected subjects

Demographic Variables	Statistical Output (Range)
Age (years)	19 - 45
Parity	1 - 8
Gestational Age (weeks)	39 - 41

Table 2: The inferior vena cava diameter on inspiration and expiration of the selected subjects before and after childbirth

Sonographic Measurements	Range (Before Childbirth)	Range (After Childbirth)
IVC diameter on inspiration (mm)	13.2 – 20.3	9.1 – 16.7
IVC diameter on expiration (mm)	17.3 – 24.8	12.6 – 21.4

Table 3: The Packed Cell Volume, heart rate, systolic blood pressure and shock index of the selected subjects before and after childbirth

Chemical Indices	Range (Before Childbirth)	Range (After Childbirth)
Packed cell volume (%)	35 – 40	18 – 33
Maternal Heart Rate (bpm)	64 – 100	70 – 100
Systolic Blood Pressure	110 – 120	90 – 120
Shock Index (HR/SBP)	0.5 – 0.9	0.6 – 0.9

Table 4: Comparison of inferior vena cava diameter during inspiration and expiration before and after childbirth

Comparison Variables	Main Rank (Before)	Main Rank (After)	P Value
IVC on inspiration	154.71	56.29	<0.001
IVC on expiration	151.45	59.55	<0.001
Packed Cell Volume	158.00	53.00	<0.001
Maternal Heart Rate	78.07	132.93	<0.001
Systolic Blood Pressure	124.52	86.48	<0.001
Shock Index	73.62	137.38	<0.001

Table 5: Correlation between inferior vena cava diameter with packed cell volume, heart rate, systolic blood pressure and shock index during inspiration and expiration before and after childbirth

Correlation Variables	Before Childbirth				After Childbirth			
	Inspiration		Expiration		Inspiration		Expiration	
	r	p	r	p	r	p	r	p
PCV	0.543	<0.001	0.512	<0.001	0.831	<0.001	0.699	<0.001
Heart Rate	-0.584	<0.001	-0.353	<0.001	-0.550	<0.001	-0.354	<0.001
Systolic B.P	-0.064	0.517	-0.119	0.228	0.100	0.310	0.033	0.740
Shock Index	-0.523	<0.001	-0.278	0.004	-0.423	<0.001	-0.269	0.006

Key: *r* represents correlation coefficient; *p* represents significance level

DISCUSSION

The finding of the study regarding the age range of the selected subjects was similar to the findings of the studies conducted by Chong *et al*. (2023) on value of IVC diameter and inferior vena cava collapse index in the evaluation of peripartum volume, in China and Oba *et al*. (2018) on the IVC diameter is a useful ultrasound finding for predicting postpartum blood loss, in Japan. The possible reasons for the similarities might be the geographic locations of the studies have nearly the same female reproductive age range. The finding regarding the parity range of the selected subjects was contrary to the studies conducted by Chong *et al*. (2023) in China and Oba *et al*. (2018) in Japan. This might be due to life styles and socio-economic status. The finding of the study regarding the gestational age of the selected subjects was similar to the findings of the studies of Chong *et al*. (2023) in China and Oba *et al*. (2018) in Japan. The possible reasons of the similarities might be the studies have not recorded fetal growth aberrations.

The findings of this study regarding to the IVC diameter ranges during inspiration and expiration before childbirth were similar to the findings of the related study conducted by Sert (2021) on prognostic capacity of IVC diameter for severe postpartum hemorrhage, in Turkey, Hernandez *et al*. (2016) on changes in sonographically measured IVC diameter in response to fluid loading in term pregnancy, in the USA. The possible reasons for the similarities might be the values obtained were within normal range of IVC diameter in pregnancy. Moreover, the findings of the study regarding to the IVC diameter ranges during inspiration and expiration after childbirth were similar to Sert (2021) in Turkey and Oba *et al*. (2018) in Japan. The possible reason might be the current and previous studies used the same method of data collection. The IVC diameter of >1.7 mm during inspiration and >2.5 mm during expiration represent a cardiac pathology (Adeyekun *et al*., 2019); in the absence of cardiac involvement is termed idiopathic.

The findings of this study regarding the PCV range of the selected subjects before childbirth are similar to the findings of the study of Oba *et al*. (2018) in Japan. The reason for the similarities might be both of the studies did not include subjects with ante partum hemorrhage and hemodynamic instabilities. The finding regarding the PCV range after childbirth was similar to the findings of the studies of Nwizi *et al*. (2011) on socio-demographic and maternal factors in anemia in pregnancy at booking in Kano, Nigeria. The possible reason for the similarities might be both studies were conducted in the same geographical location. However, the findings of this study regarding the PCV range after childbirth are contrary to the findings of the study of Oba *et al*. (2018) in Japan. The reason might be due to differences in the major factors that cause anemia in the geographical areas such as Malaria. PCV <33% after childbirth is anemic by WHO (2019). Although in the study conducted in Kano, Nigeria by Nwizi *et al*. (2011) it was adjusted to <30% due to the area of the study was a low resource setting. Severe postpartum hemorrhage (PCV <21%) can lead to implications like maternal mortality and morbidity.

The finding regarding the maternal heart rate range before delivery is similar to the finding of the related study of Green *et al*. (2020) on gestation-specific vital sign reference ranges in pregnancy, in United Kingdom. The possible reason for the similarities might be larger sample size used in both studies. Normal maternal heart rate 90 bpm increases by 15 to 20 beats per minute from the normal non-pregnant female 70 bpm (Green *et al*., 2020). The maternal heart rate <60 bpm are considered to lead to bradycardia (Green *et al*., 2020). The common causes are hypertension, heart infection, hypothyroidism and sleep apnea. The implications of bradycardia in pregnancy include trouble breathing, chest pain or pressure, hypoxia, fainting, fatigue and weakness (Cordina and McGuire 2010). The values above 100 bpm result to tachycardia and those >120 bpm are considered too high. The implications may include ectopic beats, hemodynamic instability, heart palpitations, tachycardia-induced cardiomyopathy with both mother and fetus at risk (Cordina and McGuire 2010). The finding regarding the maternal heart rate range after childbirth is similar to the finding of the study conducted by Massalha *et al*. (2021) on decreased IVC diameter as an early marker in postpartum hemorrhage, in Israel. The possible reasons for the similarities might be both studies did not include hemodynamically unstable subjects. However, the finding of this study regarding maternal heart rate is contrary to the finding of the study conducted by Oba *et al*. (2018) in Japan. Some of the values they obtained were >120 bpm which are considered severe.

The finding of this study regarding the systolic blood pressure range of the selected subjects before childbirth is contrary to the finding of the study of Green *et al*. (2021) in the United Kingdom. The possible reason might be due to higher values they obtained above normal value. The normal maternal systolic pressure is 120 mmHg. The values >130 mmHg are at risk of hypertensive crisis (Green *et al*., 2021). The clinical implications might include heart attack, heart failure, stroke kidney failure, gestational diabetes, placenta abruption, postpartum hemorrhage pregnancy related death, preeclampsia, premature birth and fetal growth restriction (Gongora and Wenger, 2015). The finding of this study regarding the systolic blood pressure range after childbirth is similar to the study conducted by Massalha *et al*. (2021) in Israel. The reason might be both the studies obtained values within normal range. The finding of this study regarding the systolic blood pressure after childbirth is contrary to the study conducted by Oba *et al*. (2018) in Japan. These might be due to socio-economic status and access to health facilities. The range of values they obtained had risks of hypotension and hypertension. The implications of the hypotension after childbirth are fainting, brain damage, fetal death, postpartum hemorrhage stroke, kidney failure and pulmonary edema (Jonard *et al*., 2014).

The finding of this study regarding the shock index range of the selected subjects before childbirth is similar to the finding of the study conducted by Le Bas *et al*. (2020) on use of the obstetric shock index as an adjunct in identifying significant blood loss in patients with massive postpartum hemorrhage, in India. The possible reason for the similarities might be the systolic blood pressures obtained are higher than the heart rates. The finding of this study regarding the shock index range after childbirth is similar to the findings of the study conducted by Nwafor *et al*. (2020) on what is the normal range of obstetric shock index in the immediate postpartum period in a low resource setting, in Abakiliki, Nigeria. The possible reasons for the similarities recorded in both studies might be owing to the conduct of the studies in the same geographic location and low resource settings. However, the finding of this study regarding the shock index range after childbirth is contrary to the study of Oba *et al*. (2018) in Japan. This might possibly be due to maternal adverse outcomes. The normal range of shock index after childbirth is 0.7 – 0.9 (Chaudhary *et al*., 2020). There is no shock index values <0.6 (Chaudhary *et al*., 2020). The shock index ≥1.4 is associated with increased mortality and morbidity (Chaudhary *et al*., 2020).

The findings of this study are similar to the findings of the studies conducted by Chong *et al*. (2023) in China and Oba *et al*. (2018) in Japan that reported the statistical difference in IVC diameter during inspiration and expiration, maternal heart rate, systolic blood pressure and shock index.

The findings of this study are similar to the findings of the study of Oba *et al*. (2018) regarding the statistical significant and strong positive correlation between IVC and PCV during inspiration and expiration before and after childbirth. The reason might be due to response of IVC to body fluid and blood volume status. Both studies did not quantify postpartum blood loss through IVC diameters but showed strong positive correlation. The finding of this current study regarding the statistical significant and strong negative correlation between IVC and maternal heart rate during inspiration before and after childbirth is contrary to the findings of the study of Akilli *et al*. (2010) on IVC diameter as a marker of early hemorrhagic shock, in Turkey. During inspiration, the IVC diameter collapsed due to negative intra-thoracic pressure that encouraged venous return to the heart. Thus, the heart rate increased. This respiratory-related change in heart rate, respiratory sinus arrhythmia (RSA), helps to match pulmonary blood floor to the lung inflation and to maintain diffusion gradient for oxygen in the lungs (Neff *et al*., 2003). The finding regarding the statistical significant and strong negative correlation between IVC and shock index during inspiration before childbirth is similar to the finding of the study of Oba *et al*. (2018). The possible reasons for the similarity might be due to increase in heart rate and decrease in systolic blood pressure during inspiration. The finding of this study regarding to the statistical significant and moderate negative correlation between IVC and shock index during inspiration after childbirth is similar to the finding of the study conducted by Akilli *et al*. (2010). The reason might be due to progressive loss in circulation of blood volume causing decrease in IVC diameter, increases heart rate and risk of severe hypovolemic shock (Taghavi *et al*., 2022). This might eventually lead to clinical implications of shock index (Akilli *et al*., 2010). The finding of this study is similar to the related studies conducted by Le Bas *et al*. (2020), Nwafor *et al*. (2020), Simoyi *et al*. (2019) on the effects of sustained inspiration and expiration on heart rate to elucidate the physical mechanics of respiratory sinus arrhythmia, in USA and Akilli *et al*. (2010) regarding the statistical significant and moderate negative correlation between IVC and maternal heart rate during expiration before delivery. The possible reasons for the similarities might be because the IVC diameter dilated during expiration due to the positive intra-thoracic pressure and heart rate decreased during expiration due to the respiratory sinus arrhythmia phenomenon. The findings regarding the statistical significant and weak negative correlation between IVC and shock index after childbirth are similar to the findings of the studies of Oba *et al*. (2018) and Akilli et *al*. (2010). The possible reasons for the similarities might be due to the decrease in the heart rate which could have contributed to decrease in shock index. The findings of this study are similar to the findings of the study of Sert (2021) who reported no statistical significant correlation between IVC and systolic blood pressure during inspiration and expiration before and after childbirth. The possible reason might be both studies recorded p-values >0.005 (indicating no significant difference exists between these variables).

CONCLUSION

In this study, the normal values of IVC diameter during inspiration and expiration before and after childbirth have been established. The IVC diameter responded to blood loss especially in subjects with severely PPH. The PCV before and after childbirth has been documented. The normal values of maternal heart rate and shock index have been documented.

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