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Evaluation of normal amniotic fluid volume with sonography in expectant Nigerian women

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Abstract

Background: Due to racial and ethnic differences in Amniotic fluid dynamics and fetal biometry, population-specific reference values for amniotic fluid volume (AFV) are essential for fetal well-being. This study addresses Nigerian women's need for such values.

Objective: To establish gestational age-specific reference ranges for normal AFV using Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) in pregnant Nigerian Women to enhance diagnosis of oligohydramnios and polyhydramnios.

Methodology: This was a prospective hospital based cross-sectional analytical study conducted at Benue State University Teaching Hospital (BSUTH), Makurdi from August 2024 to August 2025.Standardized ultrasonography was performed on 250 women with singleton pregnancies between 22 and 40 weeks using a Siemens Sonoline G-50 machine. SPSS version 23 and Microsoft Excel 2007 were used to analyze AFI and SDP measurements at $p<0.05$.

Results: The mean age of responders was 30.42 ± 3.50 years and BMI was 26.41 ± 3.84 kg/m^2. AFI was 16.75 ± 2.66 cm at 22–28 weeks and 17.57 ± 3.08 cm at 29–40 weeks with similar trends for SDP. The association between AFI and SDP was moderate ($r = 0.550$) with the regression equation AFI = 4.01 + 0.81 × SDP. Percentile analysis showed stable lower limits at late gestation, but more variability at higher percentiles. African populations had mean AFI values which were relatively higher yet clinically acceptable when compared to Western and Asian groups.

Conclusion: We established local AFI and SDP reference values to improve fetal assessment, thus creating a dependable AFV normogram for obstetrics in Nigeria.

Keywords: Amniotic Fluid Index; Fetal Well-Being; Gestational Age; Nigerian Women; Single Deepest Pocket; Sonography.

1. Introduction

Antepartum amniotic fluid volume (AFV) is a key biophysical marker reflecting fetal and placental health through dynamic physiological exchange mechanisms [1]. AFV increases in the second trimester, stabilizes in the third trimester, and declines post-term [2]. Clinical guidelines by the American College of Obstetricians and Gynecologists (ACOG) recommends that at least routine qualitative or semi- quantitative estimation and documentation of amniotic fluid

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volume be done at every ultrasound (US) visit in the second and third trimesters due to the association of amniotic fluid abnormalities with adverse pregnancy outcomes [3].

Amniotic fluid (AF) supports, among others, three main fetal functions: thermoregulation, musculoskeletal development, and gastrointestinal maturation. These functions are achieved through temperature regulation and protection against mechanical injury and infection, through AF`s cushioning and bacteriostatic effect. Additionally, AF also protects the fetus from vascular and nutritional impairment by preventing compression of the placenta and umbilical cord while allowing fetal movements and the subsequent development of the musculoskeletal system. Furthermore, fetal ingestion of AF aids in the development of the gastrointestinal system. AF is, thus, kept in a state of dynamic balance, its volume being the sum of the fluid, from the fetal lungs and urine, flowing into and out of the amniotic space, due to fetal swallowing and intramembranous absorption [4,5]. Disturbances lead to oligohydramnios or polyhydramnios with significant perinatal risk [6].

Therefore, it is imperative to establish standardized criteria for the diagnosis of polyhydramnios and oligohydramnios, as they may be dependent on other variables such as gestational age, race/ethnicity and multifetal pregnancy, so as to enhance inter-study comparisons and interactions between radiologists and sonographers who perform and interpret ultrasonographic assessments of AFV. For instance, despite the fact that there is a lack of empirical evidence regarding the earliest gestational age at which amniotic fluid volume-Ultrasound (AFV-US) measurements are best feasible, modifications are required for pregnancies that are less than 20 weeks in order to account for the fact that there are only two quadrants present during this early stage of pregnancy [7].

There are three main ways to measure AFV: indirectly, directly, or with ultrasound. Indirect measurement is performed by amniocentesis utilizing dye-dilution techniques, in which a volume of dye is injected, then aspirated forty minutes later, and analyzed. Although this method yields reliable results, it is time-consuming, invasive and necessitates further laboratory tests. Direct measurement is carried out during a hysterotomy or cesarean section [8,9]. Another way of evaluating AFV is by abdominal palpation, which involves palpating an easily felt fetal part. Although this method does not involve any invasive procedures, the results that it produces are not satisfactory [10]. Both magnetic resonance imaging (MRI) and US measurements of AFV reveal a strong association. Whilst AFV-MRI has higher accuracy than AFV- US, it is much more expensive and time-consuming, and so cannot be routinely used for the sole purpose of AFV determination [11].

Clinically, four ultrasonographic methods are used to assess AFV as follows: qualitative assessment, two semi-quantitative methods, and 2x2cm pocket technique. Qualitative assessment of AFV refers to subjective estimation of AFV by the Sonographer without sonographic measurements. After scanning the uterus, the sonographer uses his/her clinical competence to report the AFV as either oligohydramnios, normal, or polyhydramnios. A qualitative assessment of AFV by an experienced examiner has similar sensitivity as the semi-quantitative methods. Both qualitative and semi- quantitative ultrasonography approaches are said to detect normal volumes well, however, correlation with low and high AFV by dye dilution is poor [12,13].

Our research focuses on the semi-quantitative assessment of AFV, utilizing the techniques of amniotic fluid index (AFI) and the largest vertical or single deepest pocket (SDP), respectively. Compared with the single deepest pocket, which might vary with fetal position, AFI assesses serial changes in fluid volume over time. Ultrasonography, however, has other limitations, besides operator dependency. These include the possibility of underestimating amniotic fluid index (AFI) and single deepest pocket (SDP) readings secondary to high transducer pressure on the mother's abdomen, fetal position, or artefactual echoes, particularly in obese patients. It may also over estimate AFI and SDP by measuring pockets in the largest non-perpendicular diameter. Nevertheless, ultrasonography remains an important tool for assessing amniotic fluid volume (AFV) due to its ready availability, reproducibility and ease of performance [13,14].

However, the use of color Doppler ultrasound to assess AFV is controversial and fraught with caution because the procedure is thought to over-diagnose oligohydramnios, leading to more risky prenatal interventions without the requisite improvement in prenatal outcomes. If color Doppler is to be used in AFV assessments at all, the SDP technique is preferable as it appears to have the least likelihood to over-estimate low AFV [15].

When discussing amniotic fluid derangement, it is important to mention the unique instance of twin-twin transfusion syndrome since it presents with both oligohydramnios and polyhydramnios simultaneously during the same pregnancy. Given that their chorionic arteries are shared, 10-15% of diamniotic-monochorionic twins experience this condition. The diagnosis is suspected if there is a single placenta in the presence of oligohydramnios (often with growth restriction) in one twin and polyhydramnios (with fetal hydrops) in the other. Due to the high risk of maternal and fetal mortality and morbidity, current guidelines recommend screening beginning at 16 weeks and continuing every two weeks until delivery to allow for early detection, treatment, and to help guide delivery schedules in such situations [16].

The primary aim of this study was to evaluate the normal amniotic fluid volume (AFV) using sonographic measurements-specifically the Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP)-among expectant Nigerian women. The specific objectives were to establish gestational age-specific reference ranges for AFI and SDP, evaluate their relationship with gestational age, and generate locally relevant reference values to improve the diagnosis of amniotic fluid abnormalities, such as oligohydramnios and polyhydramnios. Notwithstanding the growing amount of research being done on this subject-matter elsewhere, there are still large gaps in the local knowledge base. To the best of our knowledge, no study on AFV measurement has been carried out in our environment. Prior to our study, foreign pre-determined values were used to determine the adequacy or otherwise of AFV in our community, since there exist no normogram specific to our locality.

It is hoped that this study will help to assess the AFV using AFI and SDP with the intention of also examining the link between AFV and GA and to develop a normogram peculiar to our Nigerian community. Thus, forming a basis for comparison with studies elsewhere nationally and internationally, when the need arises by clinicians in our environment.

2. Methodology

2.1. Study Setting

The study was carried out at the Radiology Department of Benue State University Teaching Hospital (BSUTH), Makurdi, Benue State, North-Central Nigeria. BSUTH is a 450^{+}-bed tertiary hospital with 18 clinical departments. It receives patients from all the 23 local government areas in Benue State and neighboring states. It is a referral and residency training center and expanded its antenatal and maternity services after assuming management of the Muhammadu Buhari Mother and Child Hospital in 2022. The state capital, Makurdi [17], is strategically accessible by road, rail and water and has a population of over 365,000 which facilitates referrals for prenatal ultrasonography.

2.2. Study Design

It was a hospital-based prospective cross-sectional analytical study conducted among 250 apparently healthy singleton pregnant women of age ≥18 years from 22nd August 2024 to 21st August 2025. Reference values for amniotic fluid volume were defined according to gestational age by using the amniotic fluid index (AFI) and single deepest pocket (SDP) techniques between 22- and 40-weeks' gestation to evaluate the correlation between these two measurements.

2.3. Study Population

The study included 250 singleton pregnant women between 22- and 40-weeks' gestation referred for routine obstetric ultrasonography.

2.4. Eligibility Criteria

2.4.1. Inclusion Criteria

Participants were included, if they were singleton pregnant women in late second or third trimester with gestational age 22 weeks or more, and referred from the BSUTH antenatal clinic to the Radiology Department for obstetric ultrasonography evaluation.

2.4.2. Exclusion Criteria

The exclusion criteria included pregnant women who failed to voluntarily give consent for the study, those with multiple gestations or co-existing uterine masses, gestational age less than 22 weeks or greater than 40 weeks, fetal abnormalities, and pregnancies complicated by maternal medical conditions including uncontrolled diabetes.

2.5. Ethical Approvals

Ethical permission was obtained from the Institutional Review Board of Benue State University Teaching Hospital (BSUTH), Makurdi on 22nd August 2024 with reference number BSUTH/MKD/HREC/2024/069. All participants provided written informed permission prior to their enrollment. The study was conducted in a way that ensured the privacy of the participants at all times. No information that could be used to identify the participants was shared.

Participants were free to cancel or drop out of the study at any moment without penalty. Doing so, did not affect their management in any way. The research was generally, conducted in accordance with the ethical principles of the Declaration of Helsinki,1964.

2.6. Data Collection and Measurements

2.6.1. Data Collection

Sociodemographic and clinical data were obtained using a structured questionnaire and patients' age and other demographic information were entered into a spreadsheet for analysis. Sonographic examinations were performed using a Siemens Sonoline G-50 ultrasound machine equipped with a curvilinear 2.0–5.0 MHz transducer, from which an appropriate mode for transabdominal ultrasonography (TAUS) was selected. After freezing the image, measurements were taken using the ultrasound machine's electronic calipers.

Following the positioning of the patient in a supine position, transabdominal ultrasound (TAUS) scanning technique was commenced, after draping a protective sheet over the adequately exposed pelvic region up to the xiphisternum, and applying coupling gel to reduce acoustic impedance between the skin and probe surface.

The volume of amniotic fluid was assessed semi-quantitatively using ultrasonography. The abdomen was divided into four quadrants by dividing the uterus into upper and lower halves using the umbilicus as reference point to calculate the standard amniotic fluid index (AFI) in centimeters. The linea nigra was also used to mark the middle of the abdomen, dividing it into left and right halves. This made it possible to measure and add up the deepest pocket in each of the four quadrants, making sure that there were no intervening fetal parts or the umbilical cord. AFI values [18,19] were traditionally classified as:

- Oligohydramnios: <5 cm
- Normal: 5–25 cm
- Polyhydramnios: >25 cm.

The probe was positioned at a right angle to the floor and parallel to the mother's sagittal plane to assesses the SDP. Pockets that were at least 1 cm wide were considered valid. For SDP, the largest vertical pocket free of fetal parts or cord was measured with the transducer held perpendicular to the floor. SDP values [18,19], were traditionally classified as:

- Oligohydramnios: <2 cm
- Normal: 2–8 cm
- Polyhydramnios: >8 cm.

2.6.2. Anthropometric Measurements

All measurements of participants' body height and weight were conducted while they were barefoot and attired in hospital gowns, adhering to established protocols, and documented in the structured questionnaire. Weight and height were measured using a SECA electronic weighing scale (model 769), made in Germany (2007). The scale holds up to 200 kg of weight and the stadiometer, 200 cm.

Participants who were weighed were instructed to take off any heavy shoes, clothes, or hair accessories and stand on a firm surface in the middle of the scale, in order to correctly record the readings in kilograms. Participants heights were measured by having them stand upright with feet flat, legs extended, arms at their sides, and shoulders aligned against the stadiometer. We used Quetelet's formula [20], to calculate the body mass index (BMI): BMI = weight (kg)/height $(m)^2$ (kg/m^2). This formula is derived from anthropometric measurements that adhere to international standards.

2.7. Sample Size Determination

We calculated the minimum sample size using the formula, for predicting a single population mean [21], $n=z^2\sigma^2/d^2$, where n = minimum sample size required, z = standard normal deviate at 95% confidence level (1.96), σ = standard deviation of amniotic fluid index (AFI), d = desired level of precision. A standard deviation (σ) of 3.0 cm was selected based on contemporary AFI reference studies and published third-trimester nomograms demonstrating comparable variability of AFI measurements in normal singleton pregnancies [1,22]. The chosen standard deviation (3.0cm) was used as a conservative and representative estimate of the variability in AFI measurements. Substituting the values into the equation, $n = (1.96)^2 \times (3.0)^2 / 0.5^2 = 3.8416 \times 9 / 0.25 = 138.3 \approx 138$.Therefore, the minimal sample size needed was 138 pregnant women. A 10% modification was made to the minimum sample size to allow for likely non-response, missing data and post-enrolment exclusions, leading to a minimum sample size of 152 participants. However, the sample size was further enlarged to boost statistical power, raise the precision of results, and enable relevant subgroup analyses across categories of gestational age. Therefore, a total of 250 singleton pregnant women was recruited by consecutive sampling method until the desired sample size was reached.

2.8. Validation of Instruments

A pilot study was done for the first 40 subjects for instrument validation to test the interobserver and intraobserver reliability of AFI and SDP measurements. Each subject was independently scanned by two competent sonographers, utilizing standardized ultrasonography protocols. AFI and SDP measurements were taken before and after each scan by the lead investigator and repeat measurements were done 5 minutes later by the second co-author. The results of the pilot study provided useful information on small changes in the measurement technique and the process of data recording to improve the consistency, reliability and accuracy of the study instruments.

2.9. Statistical Analysis

We used descriptive, exploratory and inferential statistics to analyze the data. To concisely summarize the Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) distributions, we generated descriptive statistics, which comprised the mean, standard deviation, frequencies, percentages, and certain percentiles. Scatter plot and percentile mapping were used to investigate the correlation of gestational age with parameters of amniotic fluid. Correlation and regression studies were performed to analyze the strength and relevance of these correlations and to identify typical ranges of percentiles All analyses were carried out using Microsoft Excel 2007 and SPSS version 23. Statistical significance was assessed at a level of $p < 0.05$.

3. Results

3.1. Demographic Variables of Respondents

All the 250 respondents were married, the majority of whom were between the ages of 20 and 35, urban, educated, and employed. Tivs were the predominant ethnic group 132(52.8%). Third-trimester pregnancies were common 153(61.2%), with varied gravidity/parity status. Most had no miscarriage or stillbirth history, and income was largely low to middle as depicted in table 1.

Table 1 Distribution of demographic variables of respondents(N=250)

Variable	Frequency	Percentage (%)
Age(years)		
20-35(Highest fertility)	230	92.0
36-45(Declining fertility)	20	8.0
Total	250	100.0
Marital status		
Married	250	100.0
Single	0	0.0
Total	250	100.0
Educational attainment		
Non-formal education	10	4.0
Primary education	10	4.0
Secondary education	95	38.0
Tertiary education	135	54.0
Total	250	100.0

Occupation		
Employed	154	61.6
Unemployed	96	38.4
Total	250	100.0
Ethnicity		
Tiv	132	52.8
Idoma	60	24.0
Others	58	23.2
Total	250	100.0
Residence		
Urban	212	84.8
Rural	38	15.2
Total	250	100.0
Type of obstetric scan		
Routine (From ANC)	240	96.0
Specific obstetric indications	10	4.0
Total	250	100.0
Gravidity		
1	69	27.6
2	58	23.2
3	48	19.2
4	18	7.2
≥5	57	22.8
Total	250	100.0
Parity		
0	99	39.6
1	37	14.8
2	78	31.2
3	27	10.8
≥4	9	3.6
Total	250	100.0
Gestational age		
22-28(Late 2nd semester)	97	38.8
29-40(Third trimester	153	61.2
Total	250	100.0
Miscarriage		
0	183	73.2
1	9	3.6

2	58	23.2
Total	250	100.0
Stillbirth		
0	241	96.4
1	9	3.6
Total	250	100.0
Income		
<NGN74,000(Low class)	114	45.6
NGN75,000-NGN100,000(middle class)	89	35.6
>NGH101,000(Upper class)	47	18.8
Total	250	100.0

3.2. Age and Anthropometric descriptive statistics of the study population

The mean age of the study population was 30.42 ± 3.50 years. The mean weight and height were 68.47±10.31kg and 1.62±0.05m, respectively. The mean BMI was 26.41 ± 3.84kg/m^2. All variables were somewhat positively skewed with weight skewness of 0.50. All variables showed kurtosis values near to zero, except for BMI (kurtosis = −0.59). The standard errors were minimal and the 95% confidence intervals were narrow as shown in table 2

Table 2 Age distribution and anthropometric descriptive statistics of the study population (N=250)

Variable	Mean ± SD	Median	Mode	Min-Max	Range	Skewness	Kurtosis	Std Error	95% CI (±)
Age(yrs.)	30.42 ± 3.50	30	30	23 – 40	17	0.34	0.10	0.22	0.44
Weight (Kg)	68.47± 10.31	67	60	52 – 94	42	0.50	-0.17	0.65	1.28
Height(m)	1.62 ± 0.05	1.60	1.60	1.50–1.70	0.20	0.35	-0.17	0.003	0.006
BMI (kg/m^2)	26.41 ± 3.84	25.8	23.4	18.6–34.4	15.8	0.13	-0.59	0.24	0.48

3.3. Pearson's correlation(r) analysis

This showed associations between AFI and several sociodemographic and obstetric variables. Education (r = +0.228, p < 0.001), income (r = −0.225, p = 0.001), stillbirth (r = +0.213, p < 0.001), and miscarriage (r = +0.203, p = 0.001) were reported. Age, residency status, parity, and ethnicity also showed weaker but statistically significant correlations. Gravidity, occupation, type of scan, and anthropometric indices (weight, height, and BMI) were not significantly associated with AFI, as shown in Table 3

Table 3 Distribution of Pearson's correlation coefficients (r) between AFI and selected sociodemographic variables

Sociodemographic Variable	N	Pearson's correlation (r)	*p*-value
Statistically significant association			
Age	250	-.129	<0.042
Residency status	250	-.169	<0.007
Education	250	+.228	<0.001

Ethnicity	250	-.179	0.005
Stillbirth	250	+.213	<0.001
Miscarriage	250	+.203	0.001
Parity	250	-.159	0.012
Income	250	-.225	0.001
Statistically non-significant association			
Gravidity	250	+.048	0.454
Occupation	250	-.104	0.100
Type of scan	250	-.078	0.221
Weight	250	+.390	0.100
Height	250	+.010	0.875
BMI	250	+.122	0.054

3.4. AFI Percentile Distribution in the Study Dataset Without Gestational Age Stratification

We calculated the percentile distribution of amniotic fluid index (AFI) values in our study population. Gestational age (GA) was excluded in this narrative. Calculations were performed using the PERCENTILE.INC function in Microsoft Excel 2007 (array, k) where the "array" was all observed AFI measurements and "k" was the percentile values from 0 to 1. The 3rd and 5th percentiles were 13.1cm and 13.1cm, respectively. The 10th, 25th and 50th percentiles were 14.0 cm, 15.2 cm and 16.5 cm, respectively. The 75th and 90th percentiles were calculated as 19.2 cm and 21.4 cm, and the 95th and 97th percentiles as 21.7 cm and 26.5 cm respectively, as depicted in Figure1 below.

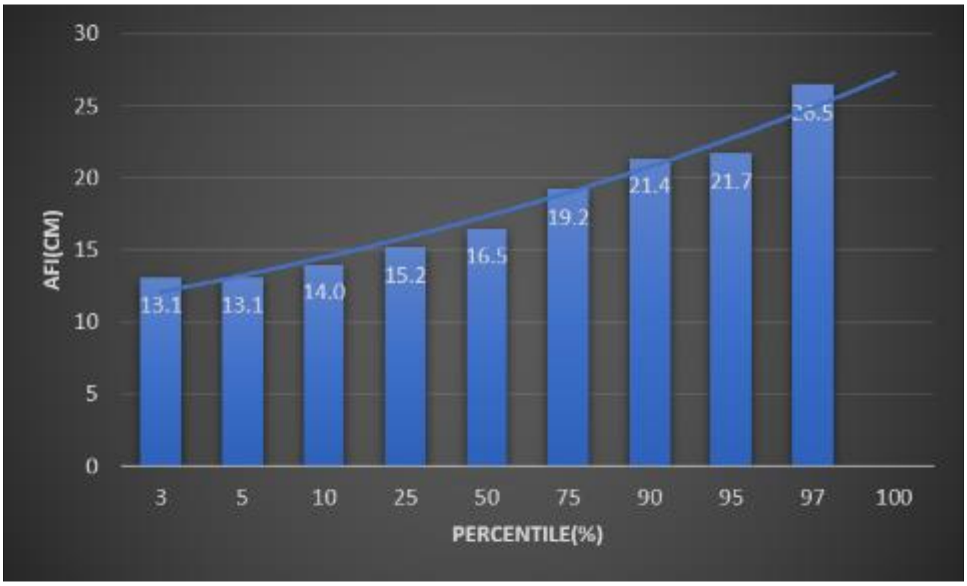

Figure 1 AFI and Percentile distribution without Gestational Age stratification

3.5. AFI and Percentile Distribution by Gestational Age

AFI and percentile distribution was shown by gestational age groups (22–28 weeks and 29–40 weeks). In the 22–28 weeks group, AFI values ranged from the 3rd to the 97th percentiles with a rather narrow interquartile range. AFI levels increased across percentiles in the higher AFI range (29-40 weeks) from 75th to 97th percentiles. Values for the 3rd and 5th percentiles were about similar in both age groups. Differences between groups were seen at higher percentiles (75th to 97th) with the 29-40weeks group having greater values. The results are shown in Figure 2, below:

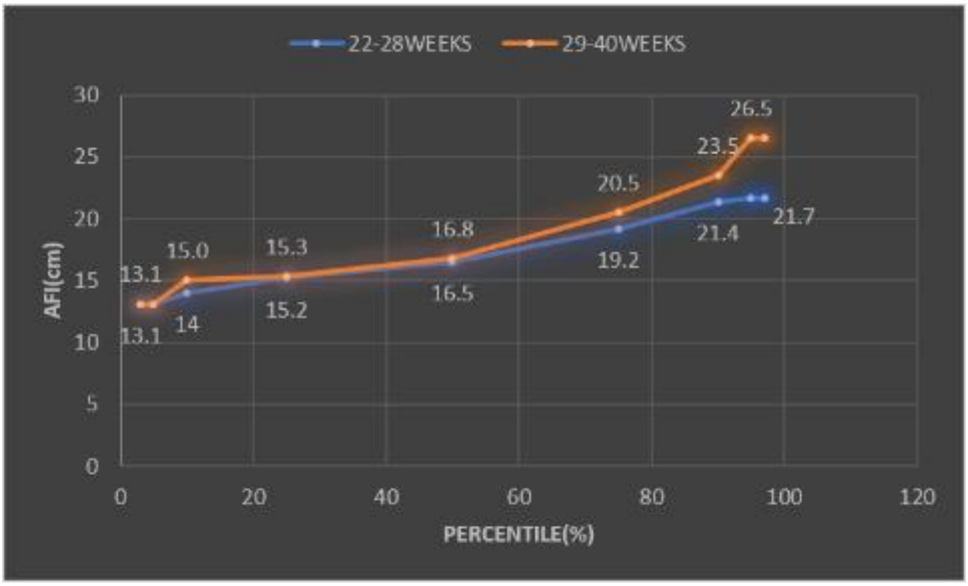

Figure 2 Distribution of AFI with Percentiles curves according to gestational age groups

3.6. The scatter plot of AFI and SDP by percentiles according to gestational age groups

3.6.1. AFI with Percentiles by Gestational Age groups

As the percentile increases in both gestational age groups, there is a progressive increase in the AFI values (Figure 3A). The 29–40week group had somewhat higher AFI values than the 22–28-week group at most percentiles, but both groups had similar distribution patterns and no apparent outliers. The highest AFI values were at the 95th and 97thpercentiles.

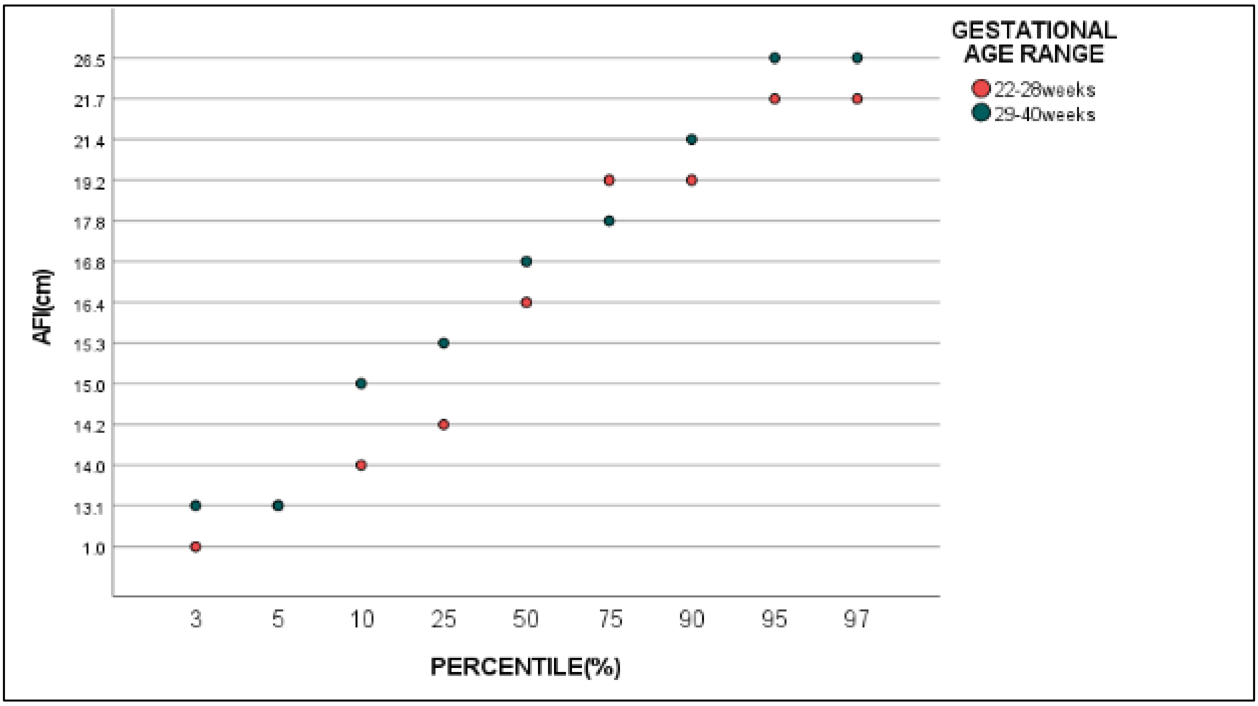

Figure 3A Scatter graph of the distribution of AFI by Percentiles according to Gestational Age groups

3.6.2. SDP with Percentiles by Gestational Age groups

The scatter plot indicated the tendency of increasing SDP values with increasing percentiles in both gestational age groups. SDP values were consistently higher in pregnancies at 22–28 weeks than at 29–40 weeks across all percentiles, with the greatest differences observed at the 95th and 97th percentiles. The lowest SDP values occurred at the 3rd percentile, whereas the highest values were recorded at the 97th percentile as shown in figure 3B, below:

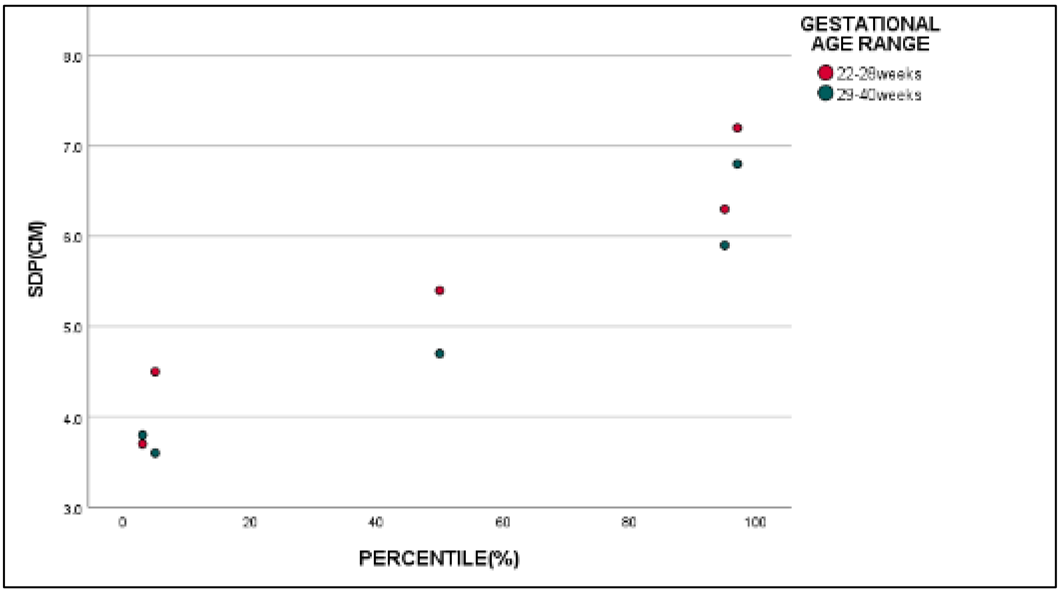

Figure 3B Scatter graph of the distribution of SDP with Percentiles by Gestational Age groups

3.7. The estimated normal and borderline ranges for AFI of our study population.

The pattern of classification of AFI using percentile cut-offs were comparable in both groups of gestational age (22-28 weeks and 29-40 weeks). Oligohydramnios was defined as AFI<13.1cm (<3rd percentile). Third(3rd) to 5th percentile range was borderline lower with 13.1cm. The normal range (5th–95th percentile) was 13.1–21.7cm. The 95th to 97th percentile was borderline upper with 21.7–26.5cm, while polyhydramnios (>97th percentile) was AFI >26.5cm. The values are shown in Table 4.

Table 4 Tabular Analysis of AFI, Normal and Borderline, Values

Gestational Age (Weeks)	Oligohydramnios (<3rd Percentile)	Borderline Lower (3rd–5th)	Normal Range (5th–95th)	Borderline Upper (95th–97th)	Polyhydramnios (>97th)
22–28	<13.1cm	13.1 – 13.1cm	13.1 – 21.7cm	21.7 – 26.5cm	>26.5cm
29–40	<13.1cm	13.1 – 13.1cm	13.1 – 21.7cm	21.7 – 26.5cm	>26.5cm

3.8. Descriptive statistics of the Amniotic Fluid Index (AFI) and the Single Deepest Pocket (SDP) according to gestational age groups of our study population.

Descriptive statistics for Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) were calculated according to gestational age groups. Mean AFI was 16.75 ± 2.66 cm and mean SDP was 5.69 ± 0.92 cm (n = 97) at 22–28 weeks. However, at 29-40 weeks (n = 153), the mean AFI was 17.57 ± 3.08 cm and the mean SDP was 5.82 ± 1.04 cm. The 29–40 weeks group had a broader range of values. These results are as given in table 5.

Table 5 Distribution of Descriptive Statistics for Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) by Gestational Age groups

Trimester	Parameter	N	Mean	Std dev	Min	Median	Max
Late 2nd Trimester(22-28weeks)	AFI	97	16.75	2.66	13.10	16.40	21.70
	SDP	97	5.69	0.92	4.40	5.80	7.30
Third trimester(29-40weeks)	AFI	153	17.57	3.08	13.10	16.80	26.50
	SDP	153	5.82	1.04	4.20	5.50	8.30

3.9. Regression Analysis of AFI and SDP

Correlation between Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) was done by regression analysis to derive prediction equations.

3.9.1. Model 1(AFI derived from SDP)

In the linear regression model, AFI and SDP were linearly positively correlated. The correlation coefficient was found to be, R=0.550. The model explained 30.2% of the variance in AFI ($R^2 = 0.302$) and was statistically significant ($F = 107.30$, $p < .001$).

The regression coefficients were:

Intercept ($\beta 0$) = 4.01 ($p < 0.0001$)

SDP coefficient (β_1) = .81 ($p < .001$)

The regression equation is: $AFI=4.01+(0.81 \times SDP)$ cm

3.9.2. Model 2(SDP from AFI)

The reverse regression model was used to predict SDP using AFI as independent variable. It was a positive linear correlation. Regression coefficients were:

Intercept ($\beta 2$) = 5.03

AFI coefficient ($\beta 3$) = 0.37

The regression equation is $SDP=5.03+(0.37x\ AFI)$ cm

The two regression models indicated a moderate positive association between AFI and SDP (R=0.550, R^2=0.302) suggesting about equal strength of the association and that the models explained 30.2% of the variance while 69.8% of the variance was attributed to other factors not included in the model. However, the regression coefficients were different as a result of the direction of prediction, providing complementary equations to estimate AFI from SDP and SDP from AFI.as shown in figure 4A, and B below:

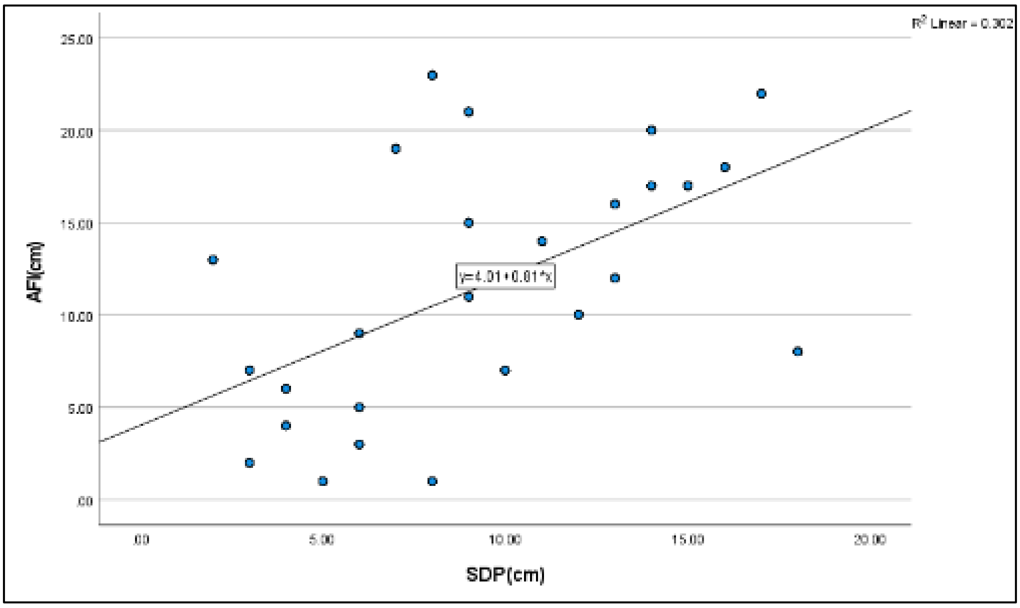

Figure 4A Scatter Plot of Linear Regression of Amniotic Fluid Index (AFI) on Single Deepest Pocket (SDP)

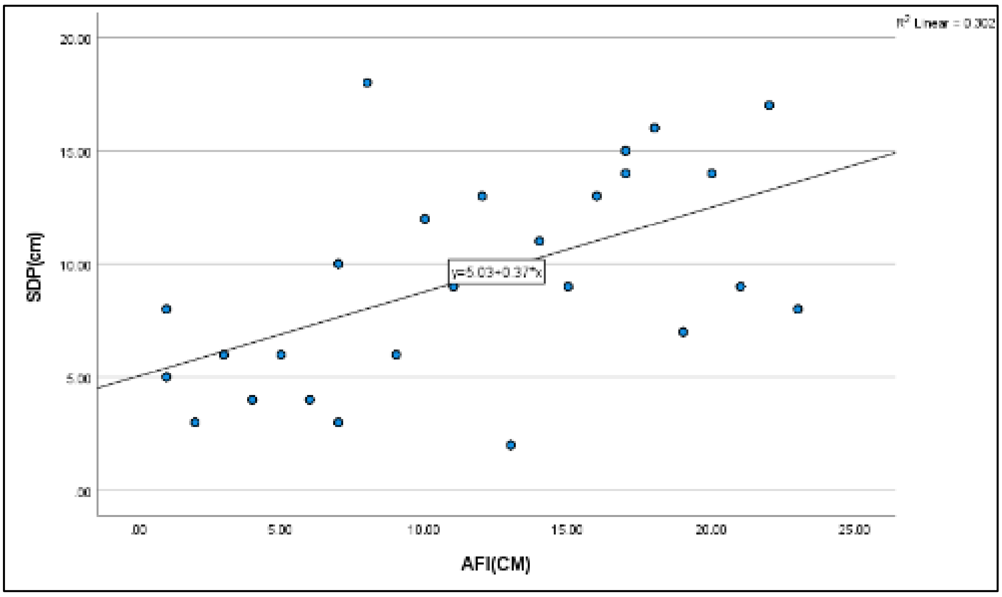

Figure 4B Scatter Plot of Linear Regression of Single Deepest Pocket (SDP) on Amniotic Fluid Index (AFI)

3.10. The distribution of our Amniotic Fluid Index (AFI) values in comparison to foundational studies from other countries in Africa, Nigeria, and the world.

AFI levels were rather constant in mid-gestation (22-28 weeks) across the included studies and more variable in late gestation (29-40 weeks). In our current Nigerian study, there was a small rise in mean AFI from 16.8 cm to 17.5 cm with a broader upper range at term. Other studies in Nigeria [23-25] reported similar mid-gestation means (16.2-16.5 cm) with mild decline or stabilization in late pregnancy. Similar patterns were identified in the Kenyan [26], Sudanese [27] and Egyptian [28] studies with mean AFI values of about 15.0–16.0 cm and almost steady trends during the course of gestation. Sudanese data indicated little stratification. In contrast, non-African [29-31] populations (USA, UK, India) had lower mean AFI values (about 13.5-14.5 cm) with a slight decline or stabilization near term. The reports from Africa generally exhibited higher mean AFI values and more variability in late gestation than those from Europe and Asia as seen in table 6.

Table 6 Comparison of Amniotic Fluid Index (AFI in cm) Values by Gestational Age in Foundational Studies from Selected Populations

Study (Location)	Gestational Age (weeks)	AFI Range (cm)	Mean AFI (cm)	Key Contribution
Nigeria, Present study	22–28	13.1–21.7	16.8	Established local reference values for AFI in Makurdi, North-central, Nigerian population
	29–40	13.1–26.5	17.5	Demonstrated increasing variability in late gestation
Nigeria, Agwu et al., 2016[23]	22–28	11.0–22.0	16.4	Provided regional AFI ranges in Southeastern Nigeria
	29–40	9.0–23.0	15.9	Showed slight decline in mean AFI at term
Nigeria, Alao et al., 2006[24]	22–28	13.0–21.0	16.5	Early AFI reference data from Southwestern Nigeria
	29–40	11.0–22.0	15.2	Highlighted gestational age-related decline
Nigeria, Anzaku et al., 2018[25]	22–28	13.0–22.0	16.2	Confirmed consistency of AFI values across Nigerian populations
	29–40	11.0–21.0	16.0	Demonstrated stable AFI trends in late pregnancy
Kenya, Sande et al., 2018[26]	22–28	10.5–21.5	15.2	Provided East African clinical AFI reference ranges
	29–40	8.5–24.5	15.4	Showed wider AFI distribution at term
Sudan, Burai et al., 2016[27]	22–28	9.0–23.0	15.5	Established AFI reference values for Sudanese population
	29–40	9.0–23.0	15.8	Limited gestational stratification but useful regional data
Egypt, Elsadek et al., 2022[28]	22–28	10–24.0	15–16	Evaluated AFI as predictor of fetal outcome in low-risk pregnancies
	29–40	10–25.0	15–16	Reinforced clinical utility of AFI in obstetric surveillance
USA, Moore et al., 1990[29]	22–28	8.0–22.0	14.5	Classic study establishing global AFI standards
	29–40	5.0–25.0	14.5	Defined lower AFI thresholds near term
UK, Nwosu et al., 1993[30]	22–28	8.5–21.0	14.5	Provided European comparative AFI values
	29–40	5.0–24.0	14.0	Demonstrated decreasing AFI at term
India, Khadilkar et al., 2003[31]	22–28	9.0–20.0	13.8	Established Asian population-specific AFI values
	29–40	6.0–22.0	13.5	Reported relatively lower AFI compared to African cohorts

4. Discussion

This study established gestational age-specific reference values for amniotic fluid volume (AFV) using the Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) among Nigerian pregnant women. The mean AFI and SDP at 22-28 weeks' gestation were 16.75 ± 2.66 cm and 5.69 ± 0.92 cm respectively. The mean values were slightly higher at 17.57

± 3.08 cm and 5.82 ± 1.04 cm for AFI and SDP respectively. at 29-40 weeks of gestation. This suggests that as gestational age increases, there is a slight increase in amniotic fluid measurements (AFI and SDP). The results, thus emphasizes the dynamic nature of AFV and the need for clinical interpretation based on gestational age [1-3,14].

The relatively stable or increasing AFV with gestation in the present study contrasts with the decline near term reported in some Western reports [9,29]. However, other Nigerian studies [1,23-25] have demonstrated similar patterns of stability or modest increases, which might reflect possible population specific variation in AFV. The range of AFV variability at the third trimester increased, especially at the upper percentiles, which is consistent with previous regional observations [23, 25] and reflects the increasing range of physiologic AFV with advancing gestational age [32, 33]. This variation underscores the essence of utilizing fixed cut-off values alone and supports the use of percentile-based reference ranges. AFI has a physiologically similar pattern among populations with a minor but clinically important regional variance [34].

African populations [23-28], have shown marginally higher but acceptable mean clinical AFI values compared to Western [29,30], and Asian [31] populations. The inequalities may be attributed to differences in genetic, environmental, nutritional and methodological factors [6,10], therefore the need for population specific reference standards to improve diagnostic accuracy and clinical decision making in obstetric ultrasound practice. The results justify the need for local reference standards since the use of foreign nomograms may lead to misdiagnosis of normal or abnormal AFV in our environment [23,25].

There was a positive correlation of moderate statistical strength between Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) (R= 0.55, figures 4A&B). This finding was consistent with prior research that showed similar relationship between these two sonographic parameters [7,35, 36]. The regression model generated in the present study indicates that SDP can be a good predictor of AFI with an explained variance of about 30.2%. Notably, according to our regression model, AFI increased by 0.81 cm for every 1 cm rise in SDP and conversely, SDP increased by about 0.37 cm for every 1 cm increase in AFI. The significant correlation indicates that AFI and SDP can be used interchangeably when one measurement is not feasible or difficult to obtain to determine AFV. However, this has practical repercussions especially in resource-poor environments, where quick assessment of AFV may be urgently needed [7,19,22]. Therefore, AFI assessment should not be completely replaced by SDP, which is more reproducible and quicker to measure than AFI, especially in borderline or severe clinical conditions, because the regression model explains only 30.2% of the variance between both parameters [7].

The percentile-based classification of AFI revealed generally constant lower bounds across gestational ages with increased dispersion at higher percentiles in our investigation. This implies that low AFV cut-offs are stable whereas the upper ranges are more variable with increasing gestation [29]. This finding helps in the distinction between physiologic amniotic fluid volume (AFV) increases and polyhydramnios, which is crucial for professional management [34]. Therefore, use of locally selected percentile cut offs may improve diagnostic accuracy and clinical decision-making [3,14].

This study also fills a big data gap in the Nigerian obstetric practice whereby, majority of clinical evaluation of AFV is based on reference values produced from non-African populations [23-25]. Reference ranges provided by this study are population-specific for our environment thus, allowing a more precise assessment of fetal wellbeing in the local context, thereby improving the reliability of obstetric ultrasound assessment and patient management [3,14].

Limitations of the Study

There are a few limitations of this study that need to be acknowledged. AFI and SDP are operator dependent and may be prone to measurement bias. However, attempts were made to reduce this utilizing established protocols. The hospital-based study may have limited generalizability and one or more cases of selection bias. Moreover, this was a cross-sectional study so we could not determine longitudinal change across gestation. Furthermore, ethnic subgroup analyses were not feasible due to inadequate sample sizes. All measurements were made on the same ultrasound equipment and this can affect the comparability with various facilities. Also, some variables such as maternal hydration, nutrition and placental functioning might not have been well controlled. These limitations notwithstanding, the findings provide useful baseline data and point to the need for a multicenter longitudinal investigation in Nigeria.

5. Conclusion

The gestational age specific reference ranges of amniotic fluid volume (AFV) of Nigerian pregnant women were determined in this study using Amniotic Fluid Index (AFI) and Single Deepest Pocket (SDP) methods. These reference ranges provide clinically useful nomogram that can increase the accuracy of AFV evaluation in Nigerian obstetric practice and mitigate the risk of misclassification of AF abnormalities associated with the use of non-population specific reference values.

The study also showed that the values of AFI in the Nigerian population are generally higher than that reported in many western and Asian populations, but still within the clinically acceptable limits. These findings highlight the necessity to set up population-specific obstetric reference standards and suggest that factors such as genetics, environment, nutrition and technical aspects may affect amniotic fluid dynamics in different populations.

These locally derived reference values may help improve the diagnosis of amniotic fluid abnormalities such as oligohydramnios and polyhydramnios, and thereby contribute to timely and appropriate clinical decision-making. This study therefore provides an evidence-based framework for improving prenatal assessment and obstetric care in Nigeria. Furthermore, multi-center studies involving larger and more diverse Nigerian populations are suggested to validate and refine these reference ranges and to increase their generalizability.

Recommendations

This study supports the use of locally generated gestational age-specific reference ranges for AFI and SDP in normal obstetric ultrasonography practice in Nigeria. These indigenous nomograms improve the accuracy of measurement of amniotic fluid and promote early diagnosis and accurate classification of oligohydramnios and polyhydramnios. Care is needed in the use of foreign reference standards as these may not take into account population specific differences. It is recommended to incorporate these local values in the ultrasound procedures and reporting templates, so as to provide continual medical education to the practitioners. In addition, there is a need for multicenter research across Nigeria to evaluate and standardize these results, therefore enhancing better fetal surveillance, improved obstetric outcomes and evidence-based maternal as well as fetal care

Compliance with ethical standards

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Disclosure of conflict of interest

The authors disclose no competing interests.

Statement of informed consent

All subjects gave written informed consent prior to enrolment. The privacy of participants was maintained at all times during the study, and no information that could be used to identify them was shared. They were also free to cancel or drop out of the study at any time without penalty and this decision did not affect their management.

Data and Materials Availability

Data are complete and can be freely provided on request by the corresponding author

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Authors' Contributions

MDC conceived and designed the project, supervised the data collection, evaluated the results, performed statistical analysis and drafted the initial as well as the final manuscript. EAE was involved in data collection, ultrasound scanning, data entry, and revision of the text. TSA assisted with ultrasound measurements, literature search and modification of the text. OJA contributed in data collection, validation of study instruments and critical revision of the text. OCA was responsible for general supervision, methodological direction, ethical oversight, and final approval of the document. TDK, helped interpret data and critically reviewed the text for key intellectual content. All authors reviewed and approved the final manuscript.

References

[1] Agwu KK, Agbo JA, Okoye IJ, Ogbu SO. Sonographic assessment of normal amniotic fluid volume in pregnant Nigerian women. *Trop J Obstet Gynaecol*. 2007;24(1):40–45.

[2] Doiron T, Ghahremani TL, Helmich M, Wendel MP, Magann EF. Amniotic fluid volume in fetal health and disease. In: *Callen's Ultrasonography in Obstetrics and Gynecology*. Clinical Tree; 2023. Available from: https://clinicalpub.com/amniotic-fluid-volume-in-fetal-health-and-disease/. Accessed 22 Jul 2026.

[3] American College of Obstetricians and Gynecologists Committee Opinion No. 828: Indications for outpatient antenatal fetal surveillance. Obstet Gynecol. 2021;137(6):e177-e197. doi:10.1097/AOG.0000000000004407. PMID:34011892.

[4] Bhangale S, Kose V. Obstetric outcome of pregnancies with borderline versus normal amniotic fluid index at term: an analytical cross-sectional study. Int J Reprod Contracept Obstet Gynecol. 2022;11(6):1734-1739. doi:10.18203/2320-1770.ijrcog20221449

[5] Fischer R. Amniotic fluid: physiology and assessment. *Glob Libr Women's Med*. 2008. doi:10.3843/GLOWM.10208.

[6] Huri M, Di Tommaso M, Seravalli V. Amniotic fluid disorders: from prenatal management to neonatal outcomes. *Children (Basel)*. 2023;10(3):561. doi:10.3390/children10030561. PMID:36980117; PMCID: PMC10047002.

[7] Magann EF, Whittington JR, Morrison JC, Chauhan SP. Amniotic fluid volume assessment: eight lessons learned. Int J Women's Health. 2021; 13:773-779. doi:10.2147/IJWH.S316841.

[8] Phelan JP, Smith CV, Broussard P, Small M. Amniotic fluid volume assessment with the four-quadrant technique at 36–42 weeks' gestation. *J Reprod Med*. 1987;32(7):540–542.

[9] Whittington JR, Chauhan SP, Wendel MP, Ghahremani TL, Pagan ME, Carter MM, Magann EF. Historical assessment, practical management, and future recommendations for abnormal amniotic fluid volumes. J Clin Med. 2024;13(16):4702. doi:10.3390/jcm13164702.

[10] Anwar N, Gurney L. Amniotic fluid in fetal life: physiology and pathophysiology. *Obstet Gynaecol Reprod Med*. 2025; 36:31–40.

[11] Moschos E, Güllmar D, Fiedler A, John U, Renz DM, Waginger M, et al. Comparison of amniotic fluid volumetry between fetal sonography and MRI—correlation to MR diffusion parameters of the fetal kidney. Birth Defects. 2017;1(1):1-7. doi:10.15761/BDJ.1000102.

[12] Panda J, Pawar P. Assessment of amniotic fluid index by ultrasonography and its association with maternal and fetal outcomes: a prospective observational study from a tertiary care center in Maharashtra. Int J Med Pharm Res. 2026;7(2):3712-3717. doi:10.5281/zenodo.19878335.

[13] Crellin HB, Singh V. Sonographic evaluation of amniotic fluid. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan–. Updated 2025 Jan 22. Available from: https://www.ncbi.nlm.nih.gov/books/NBK570623/. Accessed 2026 Jul 22.

[14] AIUM Practice Parameter for the Performance of Standard Diagnostic Obstetric Ultrasound. *J Ultrasound Med*. 2024;43(6): E20–E32. doi:10.1002/jum.16406. PMID:38224490

[15] Odibo IN, Whittemore BS, Hughes DS, Simmons PM, Ounpraseuth ST, Magann EF. Addition of color Doppler sonography for detection of amniotic fluid disturbances and its implications on perinatal outcomes. J Ultrasound Med. 2017;36(9):1875-1881. doi:10.1002/jum.14223

[16] Miller R, Miller J, Običan S, Simpson LL; Society for Maternal-Fetal Medicine (SMFM) Publications Committee. Society for Maternal-Fetal Medicine Consult Series #72: Twin-twin transfusion syndrome and twin anemia-polycythemia sequence. Am J Obstet Gynecol. 2024;231(5): B2-B17.

[17] Benue State University Teaching Hospital. *About BSUTH* [Internet]. Makurdi (NG): Benue State University Teaching Hospital; 2025 [cited 2026 Jul 25]. Available from: https://www.bsuth.org.ng/about-us

[18] Khalil A, Sotiriadis A, D'Antonio F, Da Silva Costa F, Odibo A, Prefumo F, et al. ISUOG Practice Guidelines: performance of third-trimester obstetric ultrasound scan. Ultrasound Obstet Gynecol. 2024;63(1):131-147. doi:10.1002/uog.27538.

[19] Luntsi G, Burabe FA, Ogenyi PA, Zira JD, Nwobi CI, Nkubli FB, et al. Sonographic estimation of amniotic fluid volume using the amniotic fluid index and the single deepest pocket in a resource-limited setting. J Med Ultrasound. 2019;27(2):63-68. doi: 10.4103/JMU.JMU_26_18.

[20] Eknoyan G. Adolphe Quetelet (1796–1874)—the average man and indices of obesity. Nephrol Dial Transplant. 2008;23(1):47–51. doi:10.1093/ndt/gfm517.

[21] Lwanga SK, Lemeshow S. *Sample Size Determination in Health Studies: A Practical Manual* [Internet]. Geneva: World Health Organization; 1991 [cited 2026 Jul 25]. Available from: https://iris.who.int/handle/10665/40062

[22] Jha P, Raghu P, Kennedy AM, Sugi M, Morgan TA, Feldstein V, et al. Assessment of amniotic fluid volume in pregnancy. Radiographics. 2023;43(6): e220146. doi:10.1148/rg.220146

[23] Agwu EJ, Ugwu AC, Shem SL, Abba M. Relationship of amniotic fluid index in third trimester with fetal weight and gender in a southeast Nigerian population. Acta Radiol Open. 2016;5(8):2058460116652651.

[24] Alao O, Ayoola O, Adetiloye V, Aremu A. The amniotic fluid index in normal human pregnancies in Southwestern Nigeria. Internet J Radiol. 2006;5(2).

[25] Anzaku SA, Gbala M, Dah TW, Didamson GD. Third trimester reference values of amniotic fluid index in a group of healthy Nigerian women in Jos, Nigeria. Thai J Obstet Gynaecol. 2018;26(4):255–261

[26] Sande JA, Ioannou C, Sarris I, Ohuma EO, Papageorghiou AT. Reproducibility of measuring amniotic fluid index and single deepest vertical pool throughout gestation. Prenat Diagn. 2015;35(5):434-439. doi:10.1002/pd.4504. PMID:25297394.

[27] Burai M, Daoud I, Adam M. Reference value of normal amniotic fluid index in second and third trimester among Sudanese pregnant ladies. *IOSR J Dent Med Sci*. 2016;15(7):120–122.

[28] Elsadek AH, Atef AM, Salama DN, Abdallah LM, Saada SM. Sonography assessment of amniotic fluid volume as a predictor of fetal outcome in low-risk pregnancy. *Egypt J Hosp Med.* 2022; 88:3022–3028.

[29] Moore TR, Cayle JE. The amniotic fluid index in normal human pregnancy. *Am J Obstet Gynecol*. 1990;162(5):1168–1173. doi:10.1016/0002-9378(90)90009-V. PMID:2187347.

[30] Nwosu EC, Welch CR, Manasse PR, Walkinshaw SA. Longitudinal assessment of amniotic fluid index. Br J Obstet Gynaecol. 1993;100(9):816-819. doi:10.1111/j.1471-0528. 1993.tb14305. x. PMID: 8218000.

[31] Khadilkar SS, Desai SS, Tayade SM, Purandare CN. Amniotic fluid index in normal pregnancy: an assessment of gestation-specific reference values among Indian women. **J** Obstet Gynaecol Res. 2003;29(3):136-141. doi:10.1046/j.1341-8076.2003.00089.x. PMID:12841695

[32] Brace RA. Physiology of amniotic fluid volume regulation. Clin Obstet Gynecol. 1997;40(2):280-289. doi:10.1097/00003081-199706000-00006.

[33] Majumdar A, Mallick K, Majumdar R, Patel P. Amniotic fluid index as indicator for pregnancy outcome in late third trimester. Int J Reprod Contracept Obstet Gynecol. 2023;12(10):3109-3113. doi:10.18203/2320-1770.ijrcog20232956

[34] Crosland BA, Hedges MA, Ryan KS, D'Mello RJ, McCarty OJT, Malhotra SV, et al. Amniotic fluid: its role in fetal development and beyond. J Perinatol. 2025;45(8):1163-1170. doi:10.1038/s41372-025-02313-1. Epub 2025 May 8. PMID:40341778; PMCID: PMC12354197.

[35] Bano K, Khan D, Nadeem M, Kanwal L. Comparative performance of amniotic fluid index and single deepest pocket in predicting adverse perinatal outcomes in high-risk pregnancies. J Health Wellness Community Res. 2026;4(7):1-9. doi:10.61919/1qqan594

[36] Egagifo O, Omo-Aghoja LO, Adeyinka AT. Correlation of perinatal outcomes with amniotic fluid assessment techniques in high-risk pregnancies in a tertiary hospital in Southern Nigeria. Afr Health Sci. 2021;21(3):1310-1320. doi:10.4314/ahs.v21i3.42.