Original Article

Sonographic Estimation of Amniotic Fluid Volume Using the Amniotic Fluid Index and the Single Deepest Pocket in a Resource-Limited Setting

Geofery Luntsi[1]*, Falmata Ali Burabe[1], Prince Ame Ogenyi[2], Joseph Dlama Zira[2], Nwobi Ivor Chigozie[1], Flavious Bobuin Nkubli[1], Maikudi Dauda[1]

[1]Department of Medical Radiography, College of Medical Sciences, University of Maiduguri, Maiduguri, Nigeria, [2]Department of Radiology, Abubakar Tafawa Balewa University Teaching Hospital, Bauchi, Nigeria

Abstract

Objective: To determine the normal value of amniotic fluid (AF) volume among pregnant women in a Northern Nigerian population and to determine if there is a relationship between AF index (AFI) and single deepest pocket (SDP) with anthropometric variables. **Materials and Methods:** A prospective cross-sectional study was conducted among singleton pregnant women at late second and third trimester attending the antenatal clinic in Abubakar Tafawa Balewa Teaching Hospital, Bauchi, from December 2016 to April 2017. The mean AFI and SDP were measured by sonography. Ethical approval was obtained from the institution and informed consent was sought for from all the participants. Descriptive statistics, i.e. mean, standard deviation, and correlation coefficient, were used for the analysis. **Results:** A total of 206 women, aged between 18 and 40 years, with fetal gestational ages between 22 and 39 weeks were included in the study. The values for AFI in the study ranged from 12 to 28.7 cm, with a mean value of 19.84 ± 3.64 cm, and SDP ranged from 3.7 to 9.1 cm with a mean value of 6.04 ± 1.12 cm. This study found a weak relationship between the anthropometric variables and AFI and SDP and a strong relationship between AFI and SDP with a correlation coefficient of $R = 0.901$ and $P = 0.014$. **Conclusion:** This study found the mean values for AF volume using AFI and SDP in the studied population to be 19.84 ± 3.64 cm and 6.04 ± 1.12 cm, respectively; a strong positive relationship between AFI and SDP; and a negative relationship between body mass index with AFI and SDP.

Keywords: Amniotic fluid index, single deep pocket, sonography

Introduction

Amniotic fluid (AF) is the fluid contained within the amniochorionic membrane in the uterus. It provides watery (convenience) Environment in which the fetus develops.[1] The AF originates from fetal urine and lung fluid, each of which contributes about 8 ml/kg/h and 100l/day, respectively. It serves as homeostatic (bacteriostatic, maintenance of amniotic sac integrity, prevent contraction, and maintain cervical consistency), physical (temperature regulation, prevention of fetal injury, and acting as a shock absorber), and functional (providing room for muscle exercise by fetal movement, breathing, and swallowing).[1]

Ultrasound assessment of AF has an important implication in obstetric care, and it has become an integral and important component of pregnancy assessment.[2,3] There are various methods of measuring AF, among which is the dye-dilution method; a volume of dye is injected, and after 40 min of injection, the sample will be aspirated and analyzed. This method gives accurate result, but it is invasive, is time-consuming, and requires additional laboratory investigations.[1] Abdominal palpation is also another method of assessing AF volume which involves palpation of an easily felt fetal part. This method is noninvasive but gives poor result.[4]

The sonographic method involves the measurement of the AF index (AFI), single deepest pocket (SDP) (largest vertical or

Received: 14-02-2018 **Accepted:** 18-06-2018 **Available Online:** 24-08-2018

Access this article online

Quick Response Code:

Website: www.jmuonline.org

DOI: 10.4103/JMU.JMU_26_18

Address for correspondence: Mr. Geofery Luntsi, Department of Medical Radiography, College of Medical Sciences, University of Maiduguri, Maiduguri, Nigeria. E-mail: geostuffy@unimaid.edu.ng

How to cite this article: Luntsi G, Burabe FA, Ogenyi PA, Zira JD, Chigozie NI, 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;27:63-8.

largest transverse pocket).[4] The AFI is a semi-quantitative analysis of AF volume which involves dividing the maternal abdomen into four quadrants using the linea nigra and an imaginary line running across the maternal umbilicus and perpendicular to the nigra.[1,5,6] The technique is simple, acceptable, and readily used.[7] AFI may perhaps appear to be more accurate by measuring all four quadrants. It can actually assess serial changes in fluid volume over time when compared to the single vertical pocket, which might vary due to fetal positioning. The pitfalls of using ultrasound are that excessive pressure on the maternal abdominal transducer leads to underestimation of AFI and SDP; artefactual echoes (particularly in obsessed patient) lead to underestimation of AFI and SDP; measurement of pockets in largest nonperpendicular diameter leads to overestimation of AFI and SDP;[7] however, it remains an important part of assessing fetal health.[2]

This study assesses the AF volume using SDP and AFI, with the aim of establishing normal values within the studied population.

Materials and Methods

A prospective cross-sectional study was conducted among singleton pregnant women at late second and third trimester attending the antenatal clinic in Abubakar Tafawa Balewa Teaching Hospital (ATBUTH), Bauchi, between December 2016 and April 2017. Ethical approval was obtained from the Institutional Review Board, and informed consent was obtained from all the participants. The participants' ages ranged between 18 and 40 years.

Inclusion and exclusion criteria

Singleton pregnant women referred from the antenatal clinic of ATBUTH to the Radiology Department for obstetric scan who were in their late second and third trimester of pregnancy and who consented to participate in the study were recruited for the study. Pregnant women with multiple gestations, gestation of fewer than 22 weeks, fetal anomaly, and gestations with maternal complications were excluded from the study.

Equipment used

Ultrasound machine ALOKA SSD-1000 (IP-1233EV, SN-57324, Japan), with a curvilinear transducer, with a frequency range of 3.5–5 MHz, was used for the scanning. Measurements were carried out using the electronic calipers of the ultrasound machine after freezing the image. Anthropometric parameters, such as height, weight, and body mass index (BMI) of each participant were measured, participants' heights were measured while standing against a meter rule with the head in Frankfurts' position after removing their shoes, and their weight was measured using a weighing scale ZT WHO Scale to the nearest 0.1 kg. The scanning was done by an experienced sonographer and sonologist with more than 10 years of working experience.

Scanning technique

The ultrasound examinations were carried out with the participants in the supine position. Participant's abdomen was exposed from the pelvic region to the xiphisternum, ultrasound gel was applied over the abdomen, and the transabdominal approach was used to perform the scan. The scanning begins by dividing the abdominal quadrant into four using the umbilicus as the reference point dividing the uterus into two halves, upper and lower. The linea nigra is also used as a reference point along the midline dividing the uterus into right and left halves. Measurements in centimeters of the deepest pool of AF devoid of fetal part or umbilical cord were taken at each of these quadrants, and the values summed to give the AFI. While the deepest pocket measurement was done after surveying the four quadrants, the deepest pocket of AF among the four quadrants was taken as the SDP.[1,8] The measurements were done in the deepest pool of AF devoid of fetal part or umbilical cord, taken with the long axis of the probe positioned parallel to the maternal sagittal plane and perpendicular to the plane of the floor. After scanning, demographic data such as age, weight, and height were also recorded. BMI was calculated using Quetelet's formula: BMI = weight (kg)/height (m^2).[9]

Data analysis

Descriptive statistics (mean, standard deviation, frequency, percentages) and inferential statistics (correlation coefficient) were carried out; polynomial regression was used to construct a normal range for the percentiles, using Statistical Package for the Social Science version 20.0, IBM Corp. Armonk, NY, USA.

Results

A total of 206 pregnant women who were referred for obstetric ultrasound from the antenatal clinic of ATBUTH were enrolled in the study. The participants were aged between 18 and 40 years. The fetal gestational ages (FGAs) of the participants were between 22 and 39 weeks. The mean AFI and the mean SDP obtained in the study were 19.84 ± 3.64 and 6.04 ± 1.12 cm. The FGA of 24 weeks had the highest mean AFI of 23.16 ± 3.86 cm and SDP of 6.99 ± 1.51 cm, while the FGA of 28 weeks had the least mean AFI of 17.88 ± 5.48 cm and SDP of 5.63 ± 1.79 cm as shown in Table 1.

The normal range of AF volume estimate using the AFI in the study was found 5–25 cm among 181 (87.86%) participants, while those with values above the normal range of 25 cm was found among 25 (12.14%) participants. The normal range of AF volume estimate using the SDP was 2–8 cm among 192 (93.20%) participants, while those with values above the normal range of 8 cm was found among 14 (6.80%) participants as shown in Table 2.

Table 3 shows the 95th, 50th, and 5th percentiles of AFI according to FGA. AFI did not show any continuous increment on FGA (weeks), while the percentile values were found to be higher at 95th followed by 50th and 5th, respectively, with a trend pattern of 27.57, 23.10, and 17.59 cm.

Table 4 shows the 95th, 50th, and 5th percentiles of SDP according to FGA. SDP did not show any continuous increment

Table 1: The fetal gestational age, mean and range values of amniotic fluid index and single deep pocket

FGA	Range (AFI)	Range (SDP)	Mean±SD	
			AFI (cm)	SDP (cm)
22	15.30-22.90	4.40-7.40	18.64±2.99	5.22±1.25
23	14.00-28.00	4.00-8.80	19.36±5.46	5.88±2.06
24	19.00-28.70	5.20-9.10	23.16±3.86	6.99±1.51
25	14.70-20.00	5.20-6.00	18.53±2.03	5.5±0.32
26	15.70-23.00	5.00-6.10	19.03±3.69	5.53±0.55
27	13.33-25.60	5.00-7.90	20.1±3.53	6.29±0.74
28	12.30-27.10	3.70-8.70	17.88±5.48	5.63±1.79
29	12.00-24.10	3.80-7.20	19.49±3.27	5.92±0.93
30	12.80-24.24	4.10-7.30	20.03±3.04	6.19±0.95
31	14.40-26.10	4.40-7.90	19.17±3.43	5.82±1.12
32	12.80-26.40	3.70-8.40	20.08±3.12	6.23±1.09
33	14.60-26.50	4.30-7.50	20.14±3.66	6.27±0.88
34	15.30-25.10	5.00-8.10	19.91±3.58	6.05±0.88
35	16.20-28.60	4.70-8.90	22.23±3.94	6.75±1.24
36	13.00-27.50	3.80-8.60	19.09±4.26	5.94±1.4
37	14.10-26.70	4.50-8.40	19.72±5.08	6.3±1.46
38	17.20-26.10	5.30-8.80	22.19±3.31	6.6±1.21
39	17.10-19.60	5.00-6.10	18.35±1.77	5.55±0.78
Average total	-	-	19.84±3.64	6.04±1.12

FGA: Fetal gestational age, SDP: Single deep pocket, AFI: Amniotic fluid index, SD: Standard deviation

Table 2: Normal values of amniotic fluid estimates

F (x)	AFI (cm)			SDP (cm)		
	<5	5-25	>25	<2	2-8	>8
n (%)	0 (0.00)	181 (87.86)	25 (12.14)	0 (0.00)	192 (93.20)	14 (6.80)

Normal range for AFI and SDP Magann *et al*.[20] SDP: Single deep pocket, AFI: Amniotic fluid index

on FGA (weeks) while the percentile values were found to be higher at 95th followed by 50th and 5th, respectively, with a trend of 9.03, 6.80, and 5.41 cm.

A strong positive correlation was found between AFI and SDP, $R = 0.901$, $P = 0.041$. The study also found a weak relationship between anthropometric variables with AFI and SDP and a negative relationship between BMI and both AFI and SDP, as shown in Table 5.

Table 6 shows the inter- and intra-class correlation of AFI. The inter- and intra-class correlation revealed the existence of a mutual agreement between samples based on the two observers. The AFI within observers was 0.889, $P < 0.05$ and between observers was 0.941, $P < 0.05$. This showed a strong relationship between the two observers and within the sampled variables.

Table 7 shows the inter- and intra-class correlation of SDP. Both inter- and intra-class correlation revealed the existence of a mutual agreement between observers based on the two observers. The SDP within observer was 0.682, $P < 0.05$ and between observers was 0.811, $P < 0.05$. This showed a strong relationship between the two observers and within the sampled variables.

Table 3: Mean±standard deviation and percentile charts of the amniotic fluid index

FGA	*n*	Mean±SD	Minimum	Maximum	Percentiles for AFI			
					5th	50th	95th	SD
22	5	18.16±2.99	15.30	22.90	15.46	17.60	26.90	1.85
23	5	19.36±5.46	14.00	28.00	14.34	18.50	26.52	1.87
24	8	23.16±3.86	19.00	28.70	19.14	20.35	28.21	1.88
25	6	18.53±2.03	14.70	20.00	15.50	19.35	19.93	1.90
26	3	19.03±3.69	15.70	23.00	15.97	18.40	22.54	1.92
27	15	20.10±3.54	13.33	25.60	13.93	19.60	24.62	1.93
28	6	17.88±5.48	12.30	27.10	12.48	17.30	25.40	1.95
29	16	19.49±3.27	12.00	24.10	13.65	20.05	23.42	1.97
30	18	20.03±3.04	12.80	24.80	15.27	20.15	24.80	1.98
31	15	19.17±3.43	14.40	26.10	15.10	18.30	25.40	2.00
32	23	20.08±3.12	12.80	26.40	16.18	19.80	25.02	2.02
33	13	20.14±3.66	14.60	26.50	15.50	18.80	26.26	2.03
34	16	19.91±3.58	15.30	25.10	16.20	18.55	25.01	2.05
35	17	22.23±3.94	16.20	28.60	16.44	22.60	27.57	2.07
36	19	19.09±4.26	13.00	27.50	13.99	17.90	26.60	2.08
37	12	19.72±5.08	14.10	26.70	14.21	18.55	26.15	2.10
38	7	22.89±3.31	17.20	26.10	17.59	23.10	25.71	2.12
39	2	18.35±1.77	17.10	19.60	17.23	18.35	19.48	2.14

FGA: Fetal gestational age, AFI: Amniotic fluid index, SD: Standard deviation

Table 4: Mean±standard deviation and centile charts of the single deep pocket

FGA	*n*	Mean±SD	Minimum	Maximum	Percentiles for SDP			
					5th	50th	95th	SD
22	5	5.22±1.25	4.40	7.40	4.42	4.70	6.94	1.22
23	5	5.88±2.06	4.00	8.80	4.02	5.40	8.46	1.21
24	8	6.99±1.51	5.20	9.10	5.41	6.50	9.03	1.21
25	6	5.50±0.32	5.20	6.00	5.23	5.35	5.95	1.21
26	3	5.53±0.55	5.00	6.10	5.05	5.00	6.10	1.20
27	15	6.27±0.74	5.00	7.90	5.14	6.30	7.34	1.20
28	6	5.63±1.79	3.70	8.70	3.78	5.70	8.03	1.19
29	16	5.92±0.93	3.80	7.20	4.57	6.10	7.06	1.19
30	18	6.19±0.95	4.10	7.30	5.10	6.50	7.30	1.18
31	15	5.82±1.12	4.40	7.90	4.54	5.60	7.55	1.18
32	23	6.26±1.10	3.70	8.40	5.00	6.50	7.79	1.18
33	13	6.27±0.88	4.30	7.50	4.78	6.50	7.32	1.17
34	16	6.05±0.88	5.00	8.10	5.00	6.05	7.35	1.17
35	17	6.75±1.24	4.70	8.90	4.78	6.80	8.50	1.16
36	19	5.94±1.40	3.80	8.60	4.16	5.90	8.15	1.16
37	12	6.30±1.46	4.50	8.40	4.56	6.30	8.13	1.15
38	7	6.60±1.21	5.30	8.80	5.36	6.30	8.38	1.15
39	2	5.55±0.78	5.00	6.10	5.06	5.55	6.05	1.15

FGA: Fetal gestational age, SDP: Single deep pocket, SD: Standard deviation

Table 8 shows the comparison of the present study with other published works from other studies. The reported values from this study were similar to those obtained from other studies from within Nigeria and outside Nigeria.

Discussion

Ultrasound assessment of AF has an important implication in obstetric care, and it has become an integral and important component of pregnancy assessment.[2]

AF assessment, especially in the second and third trimester, has been used as a critical component of assessing fetal well-being. Approximately 7% of all pregnancies have been shown to be complicated by an alteration in the quantity of AF in the third trimester, but with little importance to prenatal outcome.[10] However, in the second trimester, the monitoring of AF is of great importance as an alteration in the volume is frequently associated with fetal anomaly and poor prenatal outcome.[10]

This study found that the mean values of the AFI and mean values of SDP were similar to findings from previous studies by Onwuzu *et al*.[1] in Southeastern Nigeria and Chama *et al*.[11] in Northeastern Nigeria.

The results from this study suggest a normal value of AFI to be 12.4 cm and 28.2 cm at the 5th and 95th percentiles, respectively. These findings are similar to those obtained at 5th percentile by Onwuzu *et al*.[1] with 8.6 cm, Hebbar *et al*.[12] with 8.7 cm, Hinh and Ladinsky[13] with 8.8 cm, and Jeng *et al*.[14] with 8.0 cm. However, the values obtained in our study was higher than those obtained by previous studies,[11,15-18] that obtained 4.1, 5.0, 7.7, 7.9, and 7.8 cm, respectively. These variations may be due to the methods adopted in some of the studies as others were longitudinal studies, while some were cross-sectional studies, study population, and racial differences.

The values obtained at 95th percentile for AFI in this study was 28.2 cm. This corroborates with Onwuzu *et al*.[1] with 27.0 cm, Alao *et al*.[16] with 27.3 cm, Jeng *et al*.[14] with 24.0 cm, Magann *et al*.[15] with 24.0 cm, Hinh and Ladinsky[13] with 16.90 cm, and Chama *et al*.[11] with 23.40 cm. In healthy gestation, the rate of foetal urine production, lung secretion among others may be similar.[12] AF volume with values below the 5th percentile is suggestive of oligohydramnios.[1,15] Studies have reported 5th and 10th percentiles to be the lower limit of normal for AFI and 95th and 90th as the upper limit normal for AFI.[1,19]

This study found the mean value of SDP to be 6.04 ± 1.12 cm, which is in agreement with the findings of Masako *et al*.[19] in Nagasaki, who found the mean values of AF volume using the SDP to be 30, 80, and 120 mm. The normal value of SDP from this study was 3.8 cm and 9.0 cm obtained at 5th and 95th percentile, respectively. This corroborates the findings of Magann *et al*.[20] in the USA, who found the values of AF volume using the SDP to range from 2.1 to 8.0 cm. The agreement of the findings from this study with others could be an indication of the reproducibility and reliability of sonography as a tool to assess the AF.

There was a strong positive correlation between AFI and SDP, $R = 0.901$, $P < 0.05$, while a weak correlation was found between AFI and SDP with other maternal parameters such as parity, BMI, weight, and height, $P < 0.05$. These findings are in agreement with those of Onwuzu *et al*., who studied only AFI in Southeastern Nigeria. Maternal anthropometric variables such as BMI may vary across gestation and may not yield any clinical significance as this may not be the true picture of maternal weight.[1]

This study found a strong inter-class and intra-class correlation between two experienced observers who performed the scan. The correlation coefficient for AFI within observers was 0.889, $P < 0.05$ and between observers was 0.941,

Table 5: Relationship between anthropometrics variables, parity with amniotic fluid index and single deep pocket

Variables	*R*	*P*
AFI versus SDP	0.901	0.014
AFI versus parity	0.169	0.748
AFI versus height	0.251	0.632
AFI versus weight	0.449	0.371
AFI versus BMI	−0.097	0.855
SDP versus parity	0.137	0.796
SDP versus height	0.127	0.81
SDP versus weight	0.204	0.698
SDP versus BMI	−0.113	0.831

AFI: Amniotic fluid index, SDP: Single deep pocket, BMI: Body mass index

Table 6: Inter and intra-class correlation coefficient of amniotic fluid index

	Intra-class correlation	95% CI		*F*-test with true value 0			
		Lower bound	Upper bound	Value	df1	df2	Significant
Within observer	0.889	0.491	0.980	17.068	6	6	0.002
Between observer	0.941	0.659	0.990	17.068	6	6	0.002

CI: Confidence interval

Table 7: Intra-class correlation coefficient of single deep pocket

	Intra-class correlation	95% CI		*F*-test with true value 0			
		Lower bound	Upper bound	Value	df1	df2	Significant
Within observer	0.682	0.048	0.937	5.286	6	6	0.031
Between observer	0.811	0.101	0.967	5.286	6	6	0.031

CI: Confidence interval

Table 8: Comparison of 50th percentile amniotic fluid index value of present study with various previous literature

FGA (weeks)	Present study	Chama (Northeastern Nigeria)	Onwuzu (Southeastern Nigeria)	Khadilkar (India)	Junior (Brazil)	Birang (Iran)	Mongoli (China)	Moore and Cayle (USA)
16	-	-	14.5	-	-	-	-	12.1
17	-	-	14.6	-	-	-	-	12.7
18	-	-	14.6	13.0	15.0	-	7.8	13.3
19	-	-	14.6	12.0	14.9	-	8.7	13.7
20	-	17.2	14.7	13.2	14.7	12.3	9.6	14.1
21	-	-	14.7	13.9	14.6	12.5	10.3	14.3
22	17.6	18.5	14.7	14.2	14.4	12.8	11.0	14.5
23	18.5	-	14.8	14.5	14.3	12.9	11.6	14.6
24	22.6	20.2	14.8	14.7	14.1	13.0	12.2	14.7
25	19.3	-	14.8	15.7	14.0	13.9	12.7	14.7
26	18.4	20.4	14.9	15.8	13.8	13.9	13.1	14.7
27	19.6	-	14.9	16.9	13.6	14.8	13.4	14.6
28	17.3	19.6	14.9	16.2	13.5	14.5	13.6	14.6
29	20.0	-	14.9	15.0	13.3	14.5	13.8	14.5
30	20.1	17.7	15.0	14.8	13.2	14.5	13.9	14.5
31	18.3	-	15.0	14.6	13.0	14.5	14.0	14.4
32	19.8	16.7	15.0	14.4	12.9	14.3	13.9	14.4
33	18.8	-	15.1	14.0	12.7	14.1	13.8	14.3
34	18.5	14.6	15.1	14.2	12.6	14.0	13.6	14.2
35	22.6	-	15.1	13.8	12.4	13.1	13.4	14.0
36	17.9	13.8	15.2	13.5	12.3	12.9	13.1	13.8
37	18.5	-	15.2	12.8	12.1	13.0	12.7	13.5
38	23.1	9.7	15.2	12.2	12.0	13.0	12.2	13.2
39	18.3	-	14.5	-	-	12.7	-	12.7
40	-	8.8	14.6	-	-	11.1	-	12.3

FGA: Fetal gestational age

$P < 0.05$. A moderate correlation coefficient was obtained for SDP within observers to be 0.682, $P < 0.05$ and between the observers 0.811, $P < 0.05$, signifying that ultrasound is a highly reproducible and reliable technique for AF volume assessment.

The 50th percentile of the AFI in the present study was found to be similar with those obtained from previous studies[1,11,16-17,20] conducted in Nigeria and from other countries among different ethnic groups and races, with varying sample sizes. This implies that using similar methodology and equipment in the hands of a qualified sonographer and/or sonologist, the measurement of the AFI can be reproducible and reliable.

Conclusion

This study found the mean values for AF volume using AFI and SDP in the studied population to be 19.84 ± 3.64 and 6.04 ± 1.12 cm, respectively, a strong positive relationship between AFI and SDP, a weak relationship between some anthropometric variables with AFI and SDP, and a negative relationship between BMI with AFI and SDP.

Acknowledgment

We wish to thank the Head of the Department and other staff of the Radiology, ATBUTH, for their interest and support throughout this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Onwuzu SW, Eze CU, Ugwu LC, Abonyi OE, Adejoh T. Ultrasound Biometry of Normal Human Amniotic Fluid Index in Nigerian Population. Radiography; 2015. Available from: http://www.elsevier.com/locate/radi. [Last accessed on 2017 Feb 23].
2. Nash P. Amniotic fluid index. Neonatal Netw 2013;32:46-9.
3. Magann EF, Chauhan SP, Hitt WC, Dubil EA, Morrison JC. Borderline or marginal amniotic fluid index and peripartum outcomes: A review of the literature. J Ultrasound Med 2011;30:523-8.
4. Buchmann EJ. The Predictive Ability of Clinical Palpation for Estimation Amniotic Fluid Volume in Suspected Prolong Pregnancy. Master's Thesis Submitted to the Faculty of Health Science Department of Epidemiology. University of Witwatersrand; 2012.
5. 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;32:540-2.
6. Sundari MT, Himabindu P, Pavani S, Sairam MV. Study of amniotic fluid index measurements in high risk pregnancies and outcome. SAS J Med 2015;1:22-5.
7. Alessandro G, Marta S, Anna I. Amniotic fluid volume: When and how to take Action; 2014. Available from: http://www.Contemporaryobgyn.modernmedicine.com. [Last accessed on 2017 Feb 23].
8. Dubil EA, Magann EF. Amniotic fluid as a vital sign for fetal wellbeing. Australas J Ultrasound Med 2013;16:62-70.

9. Huxley R, Mendis S, Zheleznyakov E, Reddy S, Chan J. Body mass index, waist circumference and waist: hip ratio as predictors of cardiovascular risk – A review of the literature. Eur J Clin Nutr 2010;64:16-22.
10. Fisk NM, Moise KJ. Fetal therapy. Cambridge: Cambridge University Press; 1997.
11. Chama CM, Bobzom DN, Mai MA. A longitudinal study of amniotic fluid index in normal pregnancy in Nigerian women. Int J Gynaecol Obstet 2001;72:223-7.
12. Hebbar S, Rai L, Adiga P, Guruvare S. Reference ranges of amniotic fluid index in late third trimester of pregnancy: What should the optimal interval between two ultrasound examinations be? J Pregnancy 2015;2015:319204.
13. Hinh ND, Ladinsky JL. Amniotic fluid index measurements in normal pregnancy after 28 gestational weeks. Int J Gynaecol Obstet 2005;91:132-6.
14. Jeng CJ, Lee JF, Wang KG, Yang YC, Lan CC. Decreased amniotic fluid index in term pregnancy. Clinical significance. J Reprod Med 1992;37:789-92.
15. Phelan JP, Ahn MO, Smith CV, Rutherford SE, Anderson E. Amniotic fluid index measurements during pregnancy. J Reprod Med 1987;32:601-4.
16. Alao O, Ayoola O, Adetiloye A, Aremu A. The amniotic fluid index in normal human pregnancies in South Western Nigeria. Acta Med Nagaski 2012;57:41-4.
17. Mowada B, Ibrahim D, Mohammed A. Reference value of normal amniotic fluid index in second and third trimester among Sudanese pregnant ladies. IOSR J Dent Med Sci 2016;15:120-22. Available from: http://www.IOSRJournal.org. [Last accessed on 2017 Feb 23].
18. Nabhan AF, Abdelmoula YA. Amniotic fluid index versus single deepest vertical pocket: A meta-analysis of randomized controlled trials. Int J Gynaecol Obstet 2009;104:184-8.
19. Masako M, Oshida Y, Tsushi A, Muira K, Hideaki M. Ultrasound prediction of amniotic fluid volume. Acta Med Nagaski 2012;57:41-4.
20. Magann EF, Ounpraseuth S, Chauhan SP, Ranganathan AS, Dajani NK, Bergstrom J, *et al.* Correlation of ultrasound estimated with dye-determined or directly measured amniotic fluid volume revisited. Gynecol Obstet Invest 2015;79:46-9.