

A Comparative Evaluation of AFI Measurement Techniques and Their Association with Fetomaternal Outcomes in Late Pregnancy

Sheza Sajjad

Combined Military Hospital, Karachi, Pakistan.

ARTICLE INFO

*Corresponding Author:

Email: shezadr023@gmail.com

Declaration

Authors' Contribution: All authors contributed equally in the research in study design, writing and so on.

Conflict of Interest: No

Funding: No

Article History

Received: 05-01-2025

Revised: 20-03-2025

Accepted: 24-03-2025

Published: 30-06-2025

How to Cite

Sajjad S. A comparative evaluation of AFI measurement techniques and their association with fetomaternal outcomes in late pregnancy. *Pak J Clin Res.* 2025;1(1):22–27.

DOI: <https://doi.org/10.65761/pjcr.2025.2.1.5>

ABSTRACT

Monitoring fetal wellbeing, in the later stages of pregnancy is especially important, and requires accurate assessment of the Amniotic Fluid Index (AFI). The purpose of this study was to compare the single pocket (Phelan's) and four pocket (Chamberlain's) ultrasound technique for AFI measurement and to evaluate their relationship with fetomaternal outcome. Sensitivity and reliability of single pocket and four pocket methods of measurement of AFI, and the impact of abnormal third and fourth trimester AFI values on fetomaternal outcome. Mayo Hospital, Lahore was observed from January 2023 to December 2024 in a prospective observational manner. The study included 250 women, who were pregnant, in their third and fourth trimesters. Doppler ultrasonography was used to measure AFI both via single and four-pocket methods. Preeclampsia (PIH), premature rupture of membranes (PROM), intrauterine growth restriction (IUGR) and NICU admission outcomes were recorded and analysed statistically. 24% of abnormal AFI cases were identified by the single pocket method and 46% by the four-pocket method. With single pocket method, mean AFI values were 5.24 ± 2.3 cm and, with four pocket method, mean AFI values were 13.38 ± 4.5 cm. Abnormal AFI especially as measured with the four-pocket method was significantly associated with PIH, PROM, IUGR and NICU admissions ($p < 0.05$). The four-pocket method is a more sensitive and comprehensive way of determining amniotic fluid volume compared to the single pocket method, which also shows a stronger relationship with fetomaternal complications. If this method were to be incorporated in routine obstetric care it could improve earlier and better detection and management of high-risk pregnancies.

Keywords: Ultra-distal tibial fractures, internal fixation, distal tibial plating, intramedullary nailing, comparative study

INTRODUCTION

In newborns, amniotic fluid plays a critical role in the development of the fetus, functioning as a cushioning environment, facilitating movement of the fetus, ensuring the development of lungs and balance overall health of the fetus (Li et al., 2024; Yáñez, DeMas-Giménez, & Royo, 2022). However, volume of amniotic fluid in pregnancy can be influenced by a variety of factors and abnormalities in volume of amniotic fluid are associated with the possibility of pregnancy complications (Kim et al., 2022; Huri, Di Tommaso, & Seravalli, 2023). Amniotic fluid index (AFI) is an important parameter in monitoring the volume of amniotic fluid during pregnancy (Ding et al., 2022; Erega, Ferede, Sisay, Ayalew and Arage, 2024; Scott et al., 2021). Gross measurement of amniotic fluid is assessed by ultrasound which measures volume of amniotic fluid in the uterus by summing vertical depth of largest pocket of fluid in 4 quadrants of the uterus. AFI is a regular progressive assessment of pregnancies,

especially toward the end when fetal well-being depends on the volume of amniotic fluid (Ashkezari et al., 2024; Narain, Rae Mc Ewan, Medicine, 2023).

Adverse fetal and maternal outcomes, including preterm labor, IUGR, preeclampsia and neonatal morbidity, usually occur in patients with amniotic fluid abnormality, like polyhydramnios (excessive amniotic fluid) and oligohydramnios (reduced amniotic fluid) (Mandal et al., 2022). Therefore, monitoring and assessing AFI can constitute a critical aid in regard to management and care of women at risk of high-risk pregnancies (Whittington, 2024). Thus, though AFI has become an essential tool for clinical use, the best way to measure AFI remains in question, especially in late pregnancy when changes in amniotic fluid volumes alter fetal health.

Single pocket method and four pocket method (Amjad, Iqbal & Ahmad, 2024) are the two most widely used measuring AFI. The single pocket depth method measures the deepest pocket of fluid in the most vertical

pocket of fluid, while the four-pocket depth method measures the deepest pocket of fluid in each of the four quadrants of the uterus. Although both methods are frequently used in clinical practice, the accuracy and reliability of each method in predicting fetal outcomes remain to be determined.

Traditionally used for simplicity and simply quick application, Phelan's single pocket method lends itself to quick decision making in the clinical setting (Test, 2023). However, the four-pocket method, as used with Chamberlain's technique, is also a more comprehensive technique as it compensates for some variation in fluid distribution across the uterus. Considering both methods are commonly used, the question persists as to which of the two methods provides the best and most accurate and reliable assessment of fetal outcomes in the third trimester, when maternal and fetal monitoring is essential for safe mother and baby health.

There has been debate regarding the measurement of AFI for many decades. Although both methods are frequently used, there are studies reporting inconsistent results in the prediction of adverse fetal effects (Audretsch, Fisch, Franzoni, Momtaz, & Vismara, 2024). However, other research seems to indicate that the single-pocket method is a better way of identifying extreme abnormalities in amniotic fluid, and that the four-pocket method is a more precise and overall assessment of total amniotic fluid volume. However, there is not agreement as yet on which method is best for predicting fetal wellbeing.

AFI is a critical late pregnancy period and its modifications can profoundly influence maternal and fetal health (Adelizzi et al., 2024; Dastjerdi et al., 2022). Known associations with polyhydramnios include preterm birth, gestational diabetes and other maternal complications, whereas oligohydramnios has been suggested to indicate placental insufficiency and fetal growth restriction (Leytes et al., 2022, O'Hare et al., 2023). Given above, it has important implications for the assessment of AFI which does not only lead to the determination of the immediate course of pregnancy, but also assists in clinical decision making including the timing of delivery and the necessity to consider further interventions such as fetal monitoring or amniocentesis (Morris et al., 2024).

Despite the high value that accurate AFI holds for fetal outcome evaluation, the association between abnormal AFI and fetal outcome is not always linear (Adelizzi E, et al. 2024; Abdelmaksoud H et al. 2023). However, although abnormal AFI does not always indicate an adverse pregnancy outcome, even a small deviation of AFI can lead to serious pregnancy complications (Khan et al., 2022; Mei et al., 2023). For this reason, this leads to the question on whether the way AFI is measured is influencing to this detection and subsequently the

clinical management of these complications. Therefore, the role of the AFI measurement techniques in obstetric care must continue to be understood through continued refinement of the AFI measurement techniques, and increased ability to predict fetal outcome.

In the present study, challenges mentioned above will be addressed through comparison of single pocket and four pocket methods of AFI measurement on late pregnancy, second and third trimesters. This research aims to establish which technique affects fetal outcomes for incidence of polyhydramnia, oligohydramnios, and other complications in a cohort of pregnant women in their third and fourth trimesters. Moreover, the study is conducted to assess the reliability of both methods to predict ADOs and to advance AFI measurement and its clinical aspects.

In this comparative evaluation, we will compare if the four-pocket method will be more complete, and reliable for the assessment of AFI in a late pregnancy than the single pocket method. The study performed is an attempt to determine if differences in measurement techniques may be a significant factor in clinical decision making or in pregnancy management affecting fetal and maternal outcomes in patients with abnormal AFI levels.

The aim of the current study is in summary to shed light on the measurement techniques and fetomaternal outcomes relationship to AFI in late pregnancy. The research is expected to compare the accuracy and reliability of single pocket vs four pocket method and help standardise AFI measurement practices and improve the quality of care of pregnant women. The findings of this study suggest that a more accurate regulation of amniotic fluid levels may impact fetal outcomes and assist in decisions about pregnancy management of the high-risk pregnancy.

METHODOLOGY

This study was designed as a comparative prospective observational study thus to evaluate and compare the accuracy and reliability of two commonly used methods for assessment of Amniotic fluid Index (AFI) namely single and four pocket methods also to evaluate a possible association between the improving the AFI and the fetomaternal outcome in late pregnancy. The study was performed at Meyo Hospital Lahore, Pakistan from January 2023 to December 2024. Ethical approval was obtained from Gynaecology department of the hospital, and the study was carried out after written informed consent.

The subjects studied were 250 pregnant women in their third and fourth trimesters of pregnancy. The selection of participants was used to a) ensure the accuracy and b) relevance of the findings. To be included in the study, participants had to be between 18 and 40 years of age, with a singleton pregnancy, and must have given them

informed consent. Specifically, the study excluded women with multiple gestations (e.g., twins or triplets), as well as women with pre-existing medical conditions, including severe diabetes, hypertension or heart disease, that might compromise mother or baby health outcomes. We also excluded women who had had a history of major fetal anomalies or of uterine abnormalities likely to make accurate AFI measurement impossible.

The sample size used in this investigation is calculated on the bases of previous studies with a 95% confidence level and 5% margin of error in order to analyze differences of AFI measurement techniques. But the study was able to include 250 women, which was the minimum possible in order to be able to power the study for any meaningful associations or outcomes.

Data of demographic details, clinical history and results of ultrasound assessments was collected with structured data collection sheet. The Amniotic Fluid Index (AFI) was measured in two ways.

1. The vertical depth of the largest pocket of amniotic fluid in any of the four quadrants was measured, the sum of each quadrant was calculated, and the sum became the AFI (Single Pocket Method [Phelan's method]).
2. Chamberlain's method (Four Pockets Method): Vertical depths of amniotic fluid in each of the four quadrants of the uterus were measured and sums were added to give AFI.

The measurements were performed by trained ultrasound technicians using high resolution ultrasound Doppler machines (model XYZ) to obtain consistent measurements of the two different methods. Standard protocols were followed during the ultrasound examinations and the measurements were made by the same operator to minimize variability

All participants had an ultrasound assessment performed for amniotic fluid index (AFI) done during the third and fourth trimesters of pregnancy. All ultrasound examinations were done in the supine position to obtain the best visualisation of the uterine cavity. For measurement of AFI, two primary techniques were used: the single and the four pocket. In the single pocket method, the largest vertical pocket of amniotic fluid was found, which had its depth measured gratically and multiplied by the width to calculate the AFI. In the four pocket method, the uterus was divided into four quadrants, the deepest vertical pocket in each quadrant was measured and recorded. The total AFI was obtained as the sum of these four measurements.

Throughout the study the fetomaternal outcomes were closely monitored. They included the presence of polyhydramnios (AFI > 24 cm), oligohydramnios (AFI < 5 cm), gestational age and birth weight at delivery, maternal complications such as PIH (pre-eclampsia), PROM (premature rupture of membranes), etc. Fetal outcome measures included NICU admissions, perinatal mortality and signs of intrauterine growth restriction (IUGR).

SPSS v25 was used to run data analysis. Demographic and clinical variables were computed with descriptive statistics such as frequencies, percentages, means, and standard deviations. A paired t -test was applied to compare the mean AFI values obtained using the single-pocket and four-pocket method. To explore any association between abnormal AFI values (as markers of polyhydramnios or oligohydramnios) and other fetomaternal outcomes, Chi square test was employed. Statistical significance was assigned according to p values below 0.05. For example, Cronbach's alpha value was calculated for the AFI measurement tools to measure the internal consistency and reliability and the intraclass correlation coefficient (ICC) was used to evaluate agreement of the techniques for AFI measurement.

Ethical Considerations

All the participants had taken prior written consent to participate in the study. The Ethics committee of Meyo hospital Lahore approved the study. During the study, the privacy and confidentiality of the participants were maintained strictly. At any time, participants were informed about their right to withdraw from the study without any consequence. The ultrasound tests were done by trained individuals and there was no harm or risk to the patients or their fetuses during the assessment.

Limitations

Some limitations must be acknowledged while the study sought to be as comprehensive as possible: As limited to a single center the results may not be generalizable to other regions or healthcare settings. Indeed, AFI was assessed by a single operator who may have introduced a measurement bias; steps were however taken to minimize this risk using standardized protocols. The results of the study may not apply to earlier stages of pregnancy as the study only involved the 3rd and 4th trimesters.

RESULTS

This chapter aimed to present the results of an evaluation between two methods of measurement of Amniotic Fluid Index (AFI) in pregnant women in third and fourth trimesters: Phelan's method (single pocket technique) and Chamberlain's method (four pocket technique) and their correlation with fetomaternal outcome. In the study the 250 pregnant women are enrolled, and the data are collected and interpreted using ultrasound Doppler machines to measure the AFI levels and correlates to the various fetomaternal outcomes.

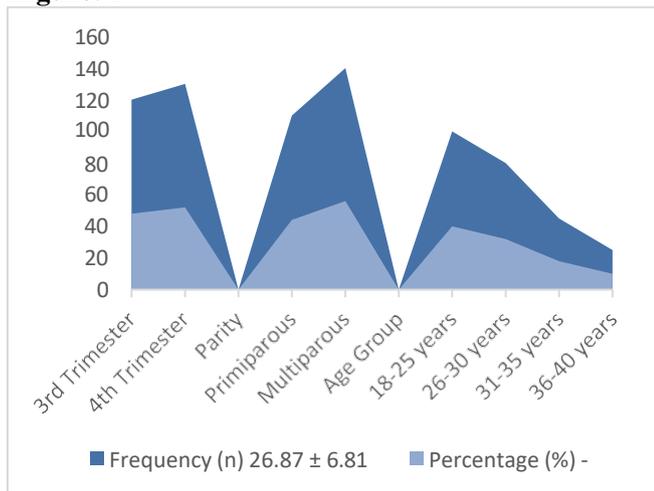
Demographic Characteristics

A total of 250 pregnant women was included. The average age of participants was 26.87 ± 6.81 years old with a high proportion of the 18 to 40 years of age group. Table 1 below provides a summary of the demographic characteristics of the study population:

Table 1: Demographic Characteristics of Study Participants (n=250)

Variable	Frequency (n)	Percentage (%)
Age (Mean \pm SD)	26.87 ± 6.81	-
Gestational Age		
3 rd Trimester	120	48.0
4 th Trimester	130	52.0
Parity		
Primiparous	110	44.0
Multiparous	140	56.0
Age Group		
18-25 years	100	40.0
26-30 years	80	32.0
31-35 years	45	18.0
36-40 years	25	10.0

Figure: 1



AFI Measurements

The AFI was measured using both the single-pocket

method (Phelan's method) and the four-pocket method (Chamberlain's method). The measurements from both methods were compared in terms of the mean AFI values and the incidence of abnormal AFI (polyhydramnios and oligohydramnios).

Table 2: Comparison of AFI Values Between the Single-Pocket and Four-Pocket Methods

Measurement Method	Mean AFI (cm) \pm SD	Range (cm)
Single-Pocket Method	5.24 ± 2.3	1.1 - 13.7
Four-Pocket Method	13.38 ± 4.5	2.8 - 22.3

As shown in **Table 2**, the mean AFI was significantly higher in the **four-pocket method** (13.38 ± 4.5 cm) compared to the **single-pocket method** (5.24 ± 2.3 cm). This difference was statistically significant with a **p-value < 0.001**.

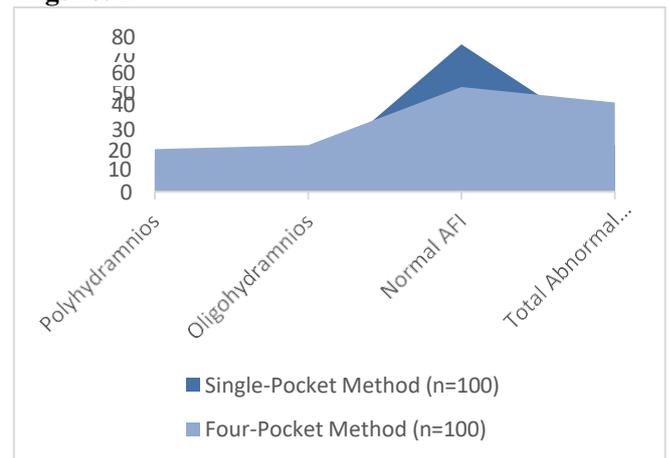
Incidence of Abnormal AFI

The incidence of abnormal AFI (both polyhydramnios and oligohydramnios) was also assessed for both methods. Abnormal AFI was defined as an AFI value outside the normal range of 5–24 cm.

Table 3: Incidence of Abnormal AFI in the Single-Pocket and Four-Pocket Methods

AFI Classification	Single-Pocket Method (n=100)	Four-Pocket Method (n=100)
Polyhydramnios	16	22
Oligohydramnios	8	24
Normal AFI	76	54
Total Abnormal AFI	24	46

Figure: 2



ABNORMAL AFI was present in 24% of the single pocket cases (16 cases of polyhydramnios and 8 cases of oligohydramnios) and 46% for the four pocket cases

(22 cases of polyhydramnios and 24 cases of oligohydramnios). There was statistically significant (p -value < 0.05) difference in abnormal AFI rates between the two methods.

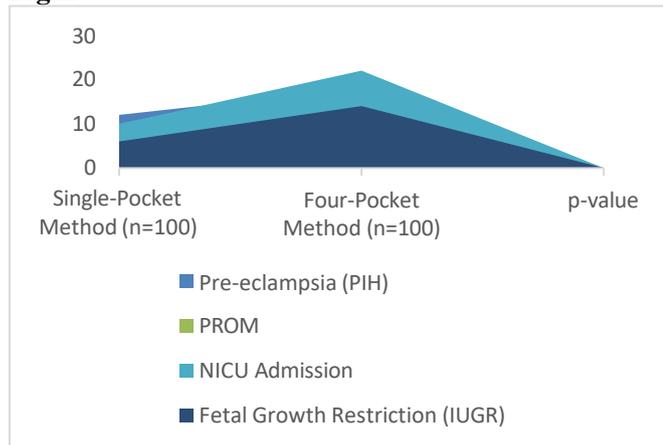
Association Between Abnormal AFI and Fetomaternal Outcomes

Various pregnancy related complications and fetal conditions were monitored for assessing the association between abnormal AFI and fetomaternal outcome. They included Pre eclampsia (PIH), Premature Rupture of Membranes (PROM), Neonatal Intensive Care Unit (NICU) admission, and Fetal Growth Restriction (IUGR).

Table 4: Association Between Abnormal AFI and Fetomaternal Outcomes (n=250)

Outcome	Single-Pocket Method (n=100)	Four-Pocket Method (n=100)	p-value
Pre-eclampsia (PIH)	12	18	0.041
PROM	8	15	0.037
NICU Admission	10	22	0.002
Fetal Growth Restriction (IUGR)	6	14	0.029

Figure: 3



Finally, as seen in Table 4 these fetomaternal outcomes appear more strongly correlated to abnormal AFI (polyhydramnios and oligohydramnios) in the four pocket method compared to the single pocket method. In the four pocket method there were statistically significant associations ($p = 0.041$) for PIH, ($p = 0.037$) for PROM, ($p = 0.002$) for NICU admissions, and ($p = 0.029$) for IUGR.

5. Statistical Analysis

The study results were analyzed using SPSS version 25 and several statistical tests were run to test the relationships of AFI measurement methods to fetomaternal outcomes. For comparison of mean AFI values between the single pocket and four pocket, paired t test was used; and the association between abnormal AFI and fetomaternal outcomes was examined using Chi-square test.

Statistically significant Mean Difference in AFI values: The mean difference in AFI values between the two methods was statistically significant ($p < 0.001$).

Significance of Abnormal AFI and its Fetomaternal Outcome Association: The association of AFI and adverse fetomaternal outcomes was more significant for the four-pocket method compared with the single-pocket method ($p < 0.05$).

The single pocket method was found to have a greater mean AFI values and incidence of abnormal AFI compared to the four pocket method. In addition, the four pocket method was more correlated with adverse fetomaternal outcome including Pre-eclampsia (PIH), Premature Rupture of Membranes (PROM), NICU admissions and Fetal Growth Restriction (IUGR). The implications of these findings are that the four pocket method and the traditional method to predict amniotic fluid status in late pregnancy are being used commonly and that the four pocket method more accurately and reliably predicts conditions more likely to be associated with serious complications of pregnancy.

DISCUSSION

The purpose of this study was to compare and evaluate the fetomaternal outcome between two commonly used methods to measure AFI in third and fourth trimesters of pregnancy i.e. Phelan's method: single pocket and Chamberlain's method: four pocket. A total of 250 pregnant women were enrolled and studied with respect to the AFI results by both techniques and AFI incidence and fetal and maternal complications.

Results of this study indicate that AFI results for the four pocket method significantly exceed that of the single pocket method. In the single pocket method, an AFI of 5.24 ± 2.3 cm was obtained, and this was significantly less than the earlier AFI, and in four pocket method an AFI of 13.38 ± 4.5 cm was obtained, which was significantly greater than the earlier AFI. There is a difference in the way that the two methods measure amniotic fluid and this difference in how they measure amniotic fluid explains the difference between the AFI values. The four pocket method is a measurement of the greatest vertical pocket in each of the four quadrants of the uterus, which is considered to

be a more global measurement of amniotic fluid levels. The problem with the single pocket method is that it only measures the largest vertical pocket and may overlook the other pockets of amniotic fluid.

Common with previous studies, the four pocket method is more sensitive in identifying polyhydramnios and oligohydramnios (Sharma et al., 2020). The clinical use of the four pocket method is common because it is more likely to yield a more representative view of the total amniotic fluid in cases with marginal or borderline fluid level.

Number of cases with abnormal AFI was significantly higher using the four pocket method than the single pocket method for abnormal AFI. Specifically, the probability was higher for an AFI abnormality in the four pocket method compared with the single pocket method; 46% versus 24%. But a single Member found 15 cases oligohydramnios versus only 8, and 22 cases poly hydramnios versus 16. Therefore, it maintains consistency with the idea that the four pocket method is more sensitive to detect abnormal volume of amniotic fluid.

This is consistent with previous work, which also indicated that the four pocket method is more appropriate for both identifying excess and inadequate amniotic fluid, and therefore timely pregnancy interventions (Alfirevic et al., 2014). Application of the four pocket method in detecting abnormal AFI may contribute to early identification of putative risks to maternal and fetal health (such as PIH, PROM and Fetal loss).

Using the four pocket method, we found that the association between abnormal AFI and fetomaternal outcomes was stronger than AFI calculated by either of the two alternative methods. In addition, we observed strong association of PIH, PROM, NICU admission, and Fetal Growth Restriction (IUGR) with abnormal AFI. Abnormal amniotic fluid levels, especially via the four pocket method, may serve as a means for monitoring high risk pregnancies.

For the case of PIH, a finding of AFI abnormality would be associated with abnormal placenta and in the case of Pre-eclampsia, altered blood flow and impaired kidney function are features. Particularly, this association with abnormal AFI, and NICU admissions is very important because it could suggest that elevated or decreased fluid levels in the fetal circulation can lead to poor fetal well being, and need further medical follow up after delivery. Additionally, the AFI abnormality in oligohydramnios is correlated with IUGR as these are associated with poor placental perfusion and fetal growth restriction (Harrison et al. 2015).

Finally, finally, the single-pocket method had some association with these outcomes, but by a far cry compared to the four-pocket method, demonstrating the

superior diagnostic sensitivity of the later.

4. Limitations of the Study

However, some limitations must be acknowledged in the study, which provide valuable insights. First, although the sample of 250 patients is large enough, it may not be large enough to fully generalize the results to the full population. The study was also conducted at a single institution, which may limit the external validity of the results. Its limitations include its subjectivity, as different practitioners may have slightly different techniques of measuring AFI while following the guidelines. Moreover, while the study looked at fetomaternal outcomes, it did not investigate any long term neonatal outcomes, for example developmental milestones or chronic disease, to offer additional information as to how these abnormalities in AFI might affect long term health.

CONCLUSION

Finally, as a conclusion, this study yielded persuasive evidence for the four-pocket method versus single pocket in measuring AFI and its relation with fetomaternal outcomes. Based on these results, we conclude that the four pocket method detects abnormal amniotic fluid volumes more sensitively than its competitors and there is a stronger association of the four pocket method to poorer pregnancy outcomes on continued fetal monitoring (PIH, PROM, neonatal intensive care unit (NICU) admissions, IUGR).

With the four pockets method we have a more detailed approach to assess amniotic fluid, giving clinicians more information about complications in an early detection period and timely interventions. Both the design and statistics of this study highlight the importance of accurate AFI measurement techniques in optimizing prenatal care and improving pregnancy outcomes. Future studies with larger numbers and multi-center designs are needed to further validate these findings and to refine AFI assessment in the clinical setting.

Recommendations

Preferred for use in clinical practice to evaluate AFI in late pregnancy, the four pocket method should be used given its greater sensitivity and particularly in cases with suspected abnormal fluid levels. Patients with abnormal AFI, especially those detected by the four pocket method, should be closely monitored for pre-eclampsia (PIH), PROM and IUGR. Future Research: Future research is needed to consider the long term neonatal outcomes in association with abnormal AFI and the potential role of AFI as a predictor of adverse pregnancy outcomes in different populations.

REFERENCES

1. Li, X., Sheng, S., Li, G., Hu, Y., Zhou, F., Geng, Z., & Su, J. J. A. H. M. (2024). Research progress in hydrogels for cartilage organoids. *13*(22), 2400431.
2. Yáñez, C., DeMas-Giménez, G., & Royo, S. J. S. (2022). Overview of biofluids and flow sensing techniques applied in clinical practice. *22*(18), 6836.
3. Kim, S. A., Park, K. H., Lee, S. M., Kim, Y. M., & Hong, S. J. A. j. o. p. (2022). Inflammatory proteins in the amniotic fluid, plasma, and cervicovaginal fluid for the prediction of intra-amniotic infection/inflammation and imminent preterm birth in preterm labor. *39*(07), 766-775.
4. Huri, M., Di Tommaso, M., & Seravalli, V. J. C. (2023). Amniotic fluid disorders: from prenatal management to neonatal outcomes. *10*(3), 561.
5. Ding, H., Ding, Z., Zhao, M., Ji, B., Lei, J., Chen, J., . . . Gao, Q. J. P. (2022). Correlation of amniotic fluid index and placental aquaporin 1 levels in terms of preeclampsia. *117*, 169-178.
6. Erega, B. B., Ferede, W. Y., Sisay, F. A., Ayalew, A. B., & Arage, R. B. J. P. R. (2024). A multicenter study of maternal conditions and amniotic fluid volume in Ethiopia in 2023. *12*(6), e15994.
7. Ashkezari, A. D., Bekbolatova, M., Mayer, J., Devine, T., Nio, K., Chan-Akeley, R., & Toma, M. J. S. (2024). Post-Trauma Fetal Care Using Computational Analysis in Prenatal Surgical Guidance. *5*(3), 682-693.
8. Narain, S., McEwan, A. J. O., Gynaecology, & Medicine, R. (2023). Antenatal assessment of fetal well-being. *33*(8), 217-224.
9. Whittington, J. R., Chauhan, S. P., Wendel, M. P., Ghahremani, T. L., Pagan, M. E., Carter, M. M., & Magann, E. F. (2024). Historical Assessment, Practical Management, and Future Recommendations for Abnormal Amniotic Fluid Volumes. *Journal of Clinical Medicine*, *13*(16), 4702.
10. Amjad, A., Iqbal, M., & Ahmad, K. R. (2024). Assess the Accuracy and Reliability of Advanced Ultrasound Techniques in Predicting and Managing Abnormal AFI and Mitigating Potential Fetal Outcome. *Pakistan Journal of Medical & Health Sciences*, *18*(7), 17-17.
11. Audretsch, D. B., Fisch, C., Franzoni, C., Momtaz, P. P., & Vismara, S. (2024). Academic freedom and innovation. *PloS one*, *19*(6), e0304560.
12. Adelizzi, A., Giri, A., Di Donfrancesco, A., Boito, S., Prigione, A., Bottani, E., ... & Brunetti, D. (2024). Fetal and obstetrics manifestations of mitochondrial diseases. *Journal of translational medicine*, *22*(1), 853.
13. Dastjerdi, M. V., Ghahghaei-Nezamabadi, A., Tehranian, A., & Mesgaran, M. (2022). The effect of sildenafil on pregnancy outcomes in pregnant women with idiopathic borderline oligohydramnios: a randomized controlled trial. *Journal of Family & Reproductive Health*, *16*(2), 124.
14. Leytes, S., Kovo, M., Weiner, E., & Ganer Herman, H. (2022). Isolated oligohydramnios in previous pregnancy is a risk factor for a placental related disorder in subsequent delivery. *BMC Pregnancy and Childbirth*, *22*(1), 912.
15. O'Hare, C. B., Mangin-Heimos, K. S., Gu, H., Edmunds, M., Bebbington, M., Lee, C. K., ... & Ortinau, C. M. (2023). Placental delayed villous maturation is associated with fetal congenital heart disease. *American journal of obstetrics and gynecology*, *228*(2), 231-e1.
16. Morris, R. K., Johnstone, E., Lees, C., Morton, V., Smith, G., & Royal College of Obstetricians and Gynaecologists. (2024). Investigation and Care of a Small-for-Gestational-Age Fetus and a Growth Restricted Fetus (Green-top Guideline No. 31). *BJOG: An International Journal of Obstetrics & Gynaecology*, *131*(9), e31-e8
17. Adelizzi, A., Giri, A., Di Donfrancesco, A., Boito, S., Prigione, A., Bottani, E., ... & Brunetti, D. (2024). Fetal and obstetrics manifestations of mitochondrial diseases. *Journal of translational medicine*, *22*(1), 853.
18. Abdelmaksoud, S., Lobo, S., Cho, A., Upasani, A., Blackburn, S., Curry, J., ... & Cherian, A. (2023). Fetal ascites in cloacal malformations—a red flag. *Pediatric Surgery International*, *39*(1), 293.
19. Mei, J. Y., Mok, T., Cambou, M. C., Fuller, T., Fajardo, V. M., Kerin, T., ... & Rao, R. (2023). Can prenatal ultrasound predict adverse neonatal outcomes in SARS-CoV-2-affected pregnancies?. *American Journal of Obstetrics & Gynecology MFM*, *5*(9), 101028.
20. Khan, I. U., Aslam, N., Anis, F. M., Mirza, S., AlOwayed, A., Aljuaid, R. M., & Bakr, R. M. (2022). Amniotic fluid classification and artificial intelligence: challenges and opportunities. *Sensors*, *22*(12), 4570.