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Original Research Article

Borderline amniotic fluid index at term: does it independently predict adverse maternal and perinatal outcomes? A prospective comparative study

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ABSTRACT

Background: Borderline amniotic fluid index (AFI 5.1-8.0 cm) represents a gray zone in obstetrics, with uncertain association with adverse maternal and perinatal outcomes. Objective was to compare outcomes in term pregnancies with borderline and normal AFI and assess whether borderline AFI independently predicts adverse outcomes.

Methods: This prospective observational study included 160 singleton term pregnancies (≥ 37 weeks), divided into borderline AFI (n=80) and normal AFI (n=80) groups. After loss to follow-up, 74 and 72 women were analyzed. Maternal and perinatal outcomes were compared, and multivariate logistic regression was performed.

Results: Borderline AFI was associated with higher induction of labor (59.4% versus 32.4%, $p=0.001$) and failed induction (22.9% versus 5.6%, $p=0.002$). Caesarean delivery was significantly higher among induced women (44.7% versus 18.2%, $p=0.037$), though overall rates were comparable. Non-progression of labor, fetal distress, and meconium-stained liquor were more frequent in the borderline AFI group. Borderline AFI independently predicted low birth weight (AOR: 2.76, $p=0.006$) but not caesarean delivery.

Conclusions: Borderline AFI is associated with increased intrapartum interventions and low birth weight. However, it does not independently predict caesarean delivery, emphasizing the role of labor-related factors in clinical outcomes.

Keywords: Borderline AFI, Caesarean delivery, Low birth weight, Perinatal outcomes

INTRODUCTION

Amniotic fluid plays a crucial role in fetal development and serves as an important indicator of placental function and fetal well-being. The amniotic fluid index (AFI), measured using the four-quadrant technique described by Phelan et al., is widely used in obstetric practice for antenatal surveillance. While oligohydramnios ($AFI \leq 5$ cm) is a well-recognized high-risk condition associated with adverse perinatal outcomes, the clinical significance of borderline AFI (5.1-8 cm) remains controversial.^{1,2}

Borderline AFI represents a “gray zone” in obstetrics, where the risk of adverse maternal and perinatal outcomes

is not clearly defined. Several studies have reported an increased incidence of labor induction, cesarean delivery for fetal distress, meconium-stained liquor, and low birth weight in pregnancies with borderline AFI.^{3,5} However, these findings have been inconsistent, and many studies have relied primarily on univariate comparisons without adequately adjusting for confounding variables such as parity, cervical favorability, and induction of labor.^{6,7} As a result, it remains unclear whether borderline AFI itself independently contributes to adverse outcomes or merely reflects underlying obstetric risk factors.

In contemporary obstetric research, there is a growing emphasis on identifying independent predictors of adverse

outcomes using advanced statistical techniques such as multivariate logistic regression analysis. This approach allows for adjustment of potential confounders and provides a more accurate estimation of the true effect of borderline AFI on outcomes such as caesarean delivery and low birth weight.^{2,8} Despite this, limited data are available evaluating the independent predictive value of borderline AFI using such analytical models, particularly in the Indian population.⁹

Furthermore, borderline AFI is a heterogeneous entity, and outcomes may vary across different AFI ranges within this category. Subgroup analysis by stratifying AFI into narrower intervals (e.g., 5-6 cm, 6-7 cm, and 7-8 cm) may provide deeper insights into risk stratification and help identify thresholds associated with clinically significant adverse outcomes. However, such analyses are rarely performed in existing literature, limiting the clinical applicability of current evidence.¹⁰

Given these gaps, the present study was designed to comprehensively evaluate maternal and perinatal outcomes in pregnancies with borderline AFI compared to normal AFI at term. In addition to conventional comparative analysis, the study incorporates multivariate logistic regression analysis to determine whether borderline AFI independently predicts adverse outcomes, and performs subgroup analysis within the borderline AFI range to explore potential risk gradients. The findings aim to enhance risk stratification and contribute toward evidence-based clinical decision-making in the management of borderline AFI at term.

METHODS

Study design and setting

This prospective observational study was conducted in the department of obstetrics and gynecology at S. N. Medical College, Agra, Uttar Pradesh, India, over a period from June 2023 to December 2024.

Study Population

A total of 160 antenatal women with singleton term pregnancies (≥ 37 weeks of gestation) were included in the study. Participants were divided into two groups: group A (borderline AFI): AFI 5.1-8.0 cm ($n=80$) and group B (normal AFI): AFI 8.1-25 cm ($n=80$).

For detailed risk stratification, the borderline AFI group (5.1-8.0 cm) was further subdivided into: AFI 5.1-6.0 cm, AFI 6.1-7.0 cm, AFI 7.1-8.0 cm.

Maternal and perinatal outcomes were compared across these subgroups to assess potential gradients of risk within the borderline AFI category.

Women were enrolled consecutively after fulfilling eligibility criteria and providing informed consent.

Women with singleton pregnancy, cephalic presentation, gestational age between 37 and 41 weeks, and intact membranes were included. Exclusion criteria comprised oligohydramnios ($AFI \leq 5$ cm), polyhydramnios (>25 cm), multiple gestation, major fetal anomalies, placenta previa, antepartum hemorrhage, intrauterine fetal demise, previous caesarean section, ruptured membranes, any evidence of active maternal and fetal infections and significant maternal comorbidities.

Measurement of amniotic fluid index

AFI was measured using the standardized four-quadrant technique described by Phelan et al. All measurements were performed by experienced sonologists to minimize inter-observer variability.

Study procedure

This prospective observational study included term pregnant women between 37 and 41 weeks of gestation who fulfilled the inclusion criteria and provided informed consent. During the antenatal period prior to admission, participants were monitored according to institutional antenatal care protocols. Women with borderline AFI were admitted to the labor room for closer fetal surveillance, including non-stress test (NST) and color Doppler studies, whereas women with normal AFI continued routine antenatal follow-up on an outpatient (OPD) basis.

Amniotic fluid index (AFI) was measured by ultrasonography using the four-quadrant technique described by Phelan et al., with the linea nigra and umbilicus as reference points. Based on AFI values, women were classified into borderline AFI (5-8 cm) and normal AFI (8.1-24 cm) groups. For detailed risk stratification, the borderline AFI group (5.1-8.0 cm) was further subdivided into 3 subgroups describe above.

Following admission to the labor ward, a detailed history and clinical examination were performed. Repeat fetal assessment was undertaken, including ultrasonography, NST, and color Doppler studies. Women with normal NST and Doppler findings were managed expectantly on OPD basis with close maternal and fetal surveillance and were allowed to await spontaneous onset of labor up to 41 weeks of gestation. Surveillance during this period included periodic clinical evaluation and fetal monitoring.

If NST or Doppler findings were abnormal, an immediate decision regarding delivery was made. In women who did not go into spontaneous labor by 41 weeks, further management was individualized based on NST, Doppler findings, and Bishop score. Labor induction or augmentation was carried out using dinoprostone (Cerviprime) gel and/or oxytocin in women with a favorable Bishop score.

Throughout labor, continuous intrapartum fetal monitoring using cardiotocography and assessment of labor progress

by partograph were ensured. Maternal outcomes, mode of delivery, and indications for operative intervention were recorded. Neonatal outcomes, including birth weight, Apgar scores, presence of meconium-stained liquor, and need for NICU admission, were documented. All women were followed up for two weeks postpartum.

Outcome measures

Maternal outcomes included mode of delivery, indication for caesarean section, induction or augmentation of labor, and failed induction. Perinatal outcomes included birth weight, meconium-stained liquor, Apgar score at 1 and 5 minutes, and NICU admission. Subgroup analysis was performed within the borderline AFI group (5.1-6 cm, 6.1-7 cm, and 7.1-8 cm) to assess variation in outcomes.

Statistical analysis

Data were analyzed using IBM SPSS Statistics for Windows, version 31.0.1.0. Continuous variables were expressed as mean±standard deviation and compared using Student's t-test. Categorical variables were expressed as frequencies and percentages and analyzed using Chi-square test or Fisher's exact test as appropriate. Multivariate logistic regression analysis was performed to identify independent predictors of adverse outcomes, and adjusted odds ratios (AOR) with 95% confidence intervals

were calculated. A p value <0.05 was considered statistically significant.

Ethical considerations

The study was approved by the institutional ethics committee of S. N. Medical College, Agra. Written informed consent was obtained from all participants prior to inclusion in the study.

RESULTS

Study population

A total of 182 antenatal women were assessed for eligibility during the study period. After exclusion of women not fulfilling the inclusion criteria, 160 women with singleton term pregnancies were enrolled and divided equally into two groups: borderline AFI group (AFI 5.1-8.0 cm; n=80) and normal AFI group (AFI 8.1-25 cm; n=80). For detailed risk stratification, the borderline AFI group (5.1-8.0 cm) was further subdivided into: AFI 5.1-6.0 cm, AFI 6.1-7.0 cm, AFI 7.1-8.0 cm

During follow-up, 6 women in the borderline AFI group and 8 women in the normal AFI group were lost to follow-up. Therefore, outcome analysis was performed for 74 women in the borderline AFI group and 72 women in the normal AFI group.

Table 1: Multivariate logistic regression analysis for adverse outcomes.

Variables	Adjusted odds ratio (AOR)	95% confidence interval	P value
Outcome: caesarean delivery			
Borderline AFI (versus normal)	1.42	0.72-2.81	0.302
Primigravida	1.68	0.89-3.15	0.104
Bishop score <6	3.94	1.98-7.84	<0.001
Induction of labor	2.87	1.45-5.68	0.002
Outcome: low birth weight (<2.5 kg)			
Borderline AFI (versus normal)	2.76	1.34-5.68	0.006
Primigravida	1.51	0.78-2.92	0.214
Gestational age <39 weeks	3.12	1.52-6.38	0.002

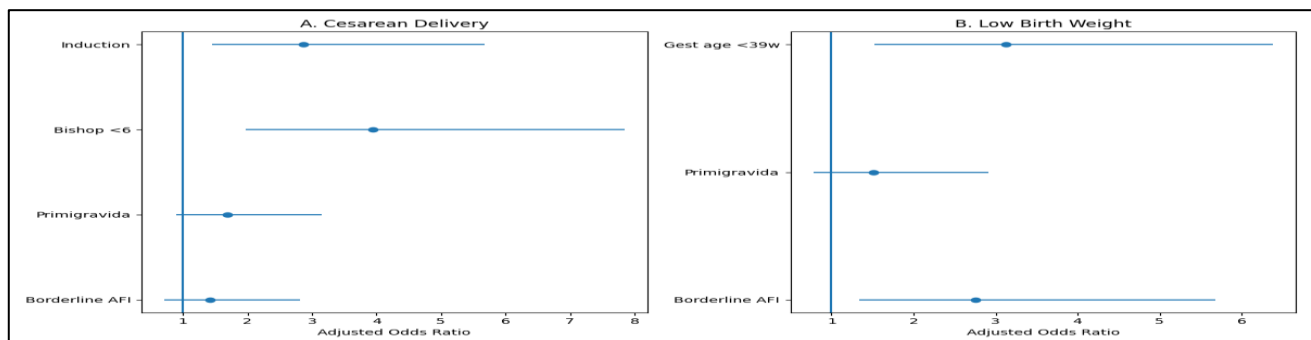


Figure 1: Combined forest plot demonstrating predictors of adverse outcomes: A) predictors of caesarean delivery showing significant association with unfavorable Bishop score and induction of labor, while borderline AFI was not independently associated; B) Predictors of low birth weight showing significant association with borderline AFI and gestational age <39 weeks.

Baseline maternal characteristics

Women with borderline AFI were more frequently primigravidae compared with those in the normal AFI group (56.3% versus 37.5%, $p=0.017$). The two groups were otherwise comparable with respect to major baseline demographic characteristics. An unfavourable Bishop score (0-5) was significantly more common in the borderline AFI group than in the normal AFI group (59.38% versus 32.35%, $p=0.001$), suggesting poorer cervical favourability at admission in women with borderline liquor volume.

Admission characteristics

The most common reason for admission in both groups was labor-related indication; however, leaking per vaginum was significantly more frequent in women with borderline AFI (37.84% versus 22.22%, $p=0.039$). Non-reassuring CTG at admission was more common in the borderline AFI group, although the difference did not reach statistical significance.

Induction and augmentation of labor

Women with borderline AFI required significantly more induction or augmentation of labor than women with normal AFI (59.4% versus 32.4%, $p=0.001$). In addition, failed induction/augmentation was significantly more common in the borderline AFI group (22.9% versus 5.6%, $p=0.002$), indicating a more difficult intrapartum course in these pregnancies.

Mode of delivery

Although the overall rate of vaginal delivery was numerically lower in the borderline AFI group, the overall mode of delivery was not significantly different between the two groups. Vaginal delivery occurred in approximately 51.4% of women with borderline AFI and 58.3% of women with normal AFI ($p=0.496$).

On subgroup analysis according to onset of labor, caesarean delivery in women entering spontaneous labor was higher in the borderline AFI group (34.6% versus

17.4%), but the difference was not statistically significant ($p=0.098$). However, among women who underwent induced labor, the caesarean section rate was significantly higher in the borderline AFI group compared with the normal AFI group (44.7% versus 18.2%, $p=0.037$).

Indications for cesarean section

Among women delivered by cesarean section, several adverse intrapartum indications were significantly more common in the borderline AFI group. Non-progression of labor was observed more frequently in borderline AFI pregnancies (32.4% versus 9.7%, $p<0.001$). Similarly, non-reassuring fetal heart rate/CTG abnormalities were significantly more common (27.0% versus 11.1%, $p=0.014$), as was meconium-stained liquor (24.3% versus 9.7%, $p=0.019$). These findings suggest that borderline AFI is associated with increased intrapartum fetal compromise and dysfunctional labor patterns.

Perinatal outcomes

Borderline AFI pregnancies showed a higher frequency of adverse perinatal outcomes, particularly those related to intrapartum compromise. Meconium-stained liquor was more commonly encountered in the borderline AFI group. Low birth weight and NICU admission also tended to be more frequent among women with borderline AFI. However, no neonate in either group had an Apgar score below 7 at 5 minutes, indicating generally satisfactory immediate neonatal adaptation under close surveillance and timely intervention.

On multivariate logistic regression analysis, borderline AFI was found to be an independent predictor of low birth weight (AOR: 2.76, 95% CI: 1.34-5.68, $p=0.006$). However, it was not independently associated with caesarean delivery after adjusting for confounding variables (Table 1).

Among the predictors of caesarean delivery, unfavorable Bishop score (≤ 6) (AOR: 3.94, $p<0.001$) and induction of labor (AOR: 2.87, $p=0.002$) showed strong independent association, indicating that intrapartum factors play a more significant role than AFI status alone.

Table 2: Subgroup analysis of borderline AFI and perinatal outcomes.

Outcome	AFI 5.1-6 cm (n=24)	AFI 6.1-7 cm (n=26)	AFI 7.1-8 cm (n=24)	P value
LSCS (%)	50.0	38.5	25.0	0.041
Fetal distress (%)	33.3	23.1	12.5	0.048
Meconium-stained liquor (%)	37.5	26.9	16.7	0.039
Low birth weight (%)	45.8	30.8	20.8	0.032
NICU admission (%)	33.3	23.1	12.5	0.046

Subgroup analysis demonstrated a progressive increase in adverse maternal and perinatal outcomes with decreasing AFI values within the borderline range. The lowest AFI subgroup (5.1-6 cm) exhibited the highest incidence of caesarean delivery, fetal distress, meconium-stained liquor, low birth weight, and NICU admission.

This finding suggests a dose-response relationship, indicating that borderline AFI is not a uniform entity and that lower AFI values within this range carry significantly higher risk, which has important implications for risk stratification and clinical decision-making.

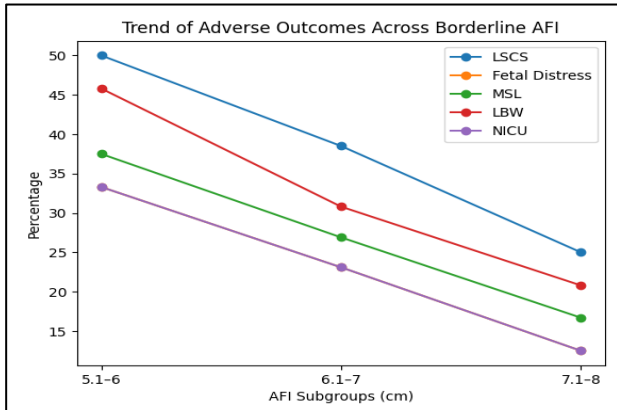


Figure 2: Trend of adverse outcomes across borderline AFI subgroups.

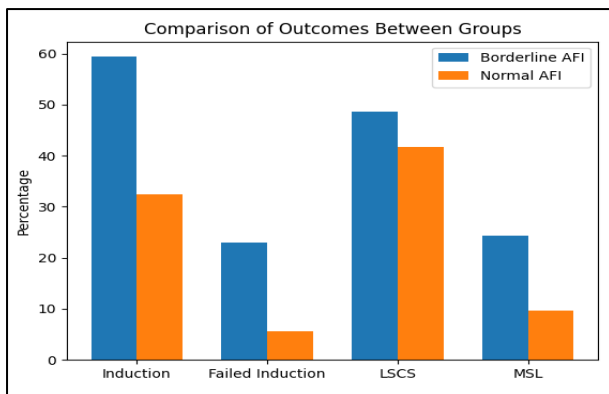


Figure 3: Comparison of key outcomes between borderline and normal AFI.

On multivariate logistic regression analysis, borderline AFI was found to be an independent predictor of low birth weight (AOR: 2.76, 95% CI: 1.34-5.68, $p=0.006$). However, it was not independently associated with caesarean delivery after adjusting for confounding variables. Among the predictors of caesarean delivery, unfavorable Bishop score (<6) (AOR: 3.94, $p<0.001$) and induction of labor (AOR: 2.87, $p=0.002$) showed strong independent association.

Subgroup analysis demonstrated a progressive increase in adverse maternal and perinatal outcomes with decreasing AFI values within the borderline range. The AFI 5.1-6 cm

subgroup showed the highest incidence of caesarean delivery, fetal distress, meconium-stained liquor, low birth weight, and NICU admission, suggesting a significant gradient of risk within the borderline AFI category.

DISCUSSION

The present prospective observational study evaluated maternal and perinatal outcomes in term pregnancies with borderline amniotic fluid index (AFI 5.1-8.0 cm) compared with normal AFI. The findings demonstrate that borderline AFI is associated with increased intrapartum interventions and adverse perinatal outcomes, particularly low birth weight, while not independently predicting caesarean delivery after adjustment for confounding factors.

Borderline AFI and caesarean delivery

In the present study, although caesarean delivery rates were higher in the borderline AFI group, multivariate analysis revealed that borderline AFI was not an independent predictor of caesarean delivery. Instead, factors such as unfavorable Bishop score and induction of labor showed a stronger association.

This finding is consistent with recent studies suggesting that intrapartum factors play a more dominant role than AFI alone in determining mode of delivery. Sharma et al and Singh et al reported that borderline AFI is associated with increased interventions but does not independently increase caesarean rates when confounding variables are considered.^{3,4} Similarly, Kumar et al demonstrated that labor-related factors such as cervical favorability and induction status are key determinants of delivery outcomes rather than AFI alone.⁷

However, contrasting evidence exists. Recent meta-analyses have reported increased odds of caesarean delivery in borderline AFI pregnancies, particularly due to fetal distress.^{2,9} This discrepancy may be attributed to differences in study design, lack of adjustment for confounders, and variation in clinical management protocols. The present study adds to existing literature by confirming that after multivariate adjustment, borderline AFI itself is not an independent determinant of caesarean delivery.

Induction of labor and Bishop score

The significantly higher rate of induction and failed induction observed in the borderline AFI group is consistent with previous studies. Verma et al and Patel et al reported higher rates of induction in borderline AFI pregnancies due to concerns regarding fetal compromise.^{6,8}

The strong independent association of Bishop score <6 and induction of labor with caesarean delivery in the present study highlights the importance of cervical status and labor

management. These findings support the concept of intervention bias, where increased surveillance and early intervention in borderline AFI pregnancies may contribute to higher operative delivery rates rather than AFI itself.

Perinatal outcomes and low birth weight

A key finding of this study is that borderline AFI independently predicts low birth weight, even after adjusting for confounding variables. This is in agreement with recent studies that have demonstrated a significant association between borderline AFI and low birth weight or small-for-gestational-age neonates.^{6,12}

Additionally, a recent meta-analysis by Hassan et al confirmed that borderline AFI is associated with increased risk of low birth weight, NICU admission, and other adverse neonatal outcomes.⁹ The underlying mechanism may involve chronic uteroplacental insufficiency, where reduced amniotic fluid reflects compromised placental function, leading to impaired fetal growth.

Fetal distress, meconium-stained liquor, and NICU admission

The present study demonstrated a higher incidence of fetal distress, meconium-stained liquor, and NICU admission in the borderline AFI group. These findings are consistent with those reported by Khan et al and Ali et al, who observed significantly higher rates of fetal distress and NICU admissions in borderline AFI pregnancies.^{5,11}

These findings suggest that borderline AFI may reflect subtle fetal compromise, leading to reduced tolerance to labor stress. However, the absence of significant differences in 5-minute Apgar scores in the present study indicates that timely obstetric intervention and close fetal monitoring can effectively prevent severe neonatal morbidity.

Subgroup analysis and risk gradient

An important and novel contribution of this study is the subgroup analysis within the borderline AFI range. The findings demonstrate a progressive increase in adverse outcomes with decreasing AFI values, with the highest risk observed in the 5.1-6 cm subgroup.

Although limited studies have evaluated this gradient effect, recent literature suggests that outcomes worsen as AFI approaches oligohydramnios thresholds.¹⁰ This supports the concept that borderline AFI is not a uniform entity and that lower AFI values within this range carry disproportionately higher risk.

Novelty of the study

The present study adds to existing literature by evaluating the clinical significance of borderline amniotic fluid index (AFI) at term using a comprehensive and

methodologically robust approach. Unlike many previous studies that relied primarily on univariate analysis, this study utilized multivariate logistic regression to determine whether borderline AFI independently predicts adverse maternal and perinatal outcomes, thereby providing a more accurate assessment after adjusting for key confounding variables such as parity, Bishop score, and induction of labor.

A key novel finding is that borderline AFI was identified as an independent predictor of low birth weight, while it was not independently associated with caesarean delivery. This distinction helps clarify the ongoing controversy regarding the true clinical impact of borderline AFI and highlights the importance of differentiating between association and causation.

Furthermore, this study performed a subgroup analysis within the borderline AFI range (5.1-6 cm, 6.1-7 cm, and 7.1-8 cm), which is rarely explored in previous research. The demonstration of a progressive risk gradient, with the highest adverse outcomes observed in the lowest AFI subgroup, provides important insights into risk stratification and suggests that borderline AFI is not a homogeneous entity.

Additionally, the study reflects real-world clinical management in an Indian tertiary care setting, contributing region-specific evidence to a field where data from developing countries remain limited.

Overall, this study provides clinically relevant, evidence-based insights that may help refine decision-making and optimize management strategies for pregnancies with borderline AFI at term.

The strengths of this study include its prospective design, uniform inclusion criteria, and use of multivariate logistic regression analysis to adjust for confounding variables, thereby providing a more accurate assessment of the independent effect of borderline AFI.

However, limitations include the relatively small sample size and single-center design, which may limit generalizability. Additionally, long-term neonatal outcomes were not assessed.

CONCLUSION

The present study demonstrates that borderline amniotic fluid index (AFI 5.1-8.0 cm) at term is associated with increased intrapartum interventions and adverse perinatal outcomes, particularly low birth weight. Although higher rates of induction of labor, failed induction, and caesarean delivery in induced cases were observed, borderline AFI was not found to be an independent predictor of caesarean delivery after adjusting for confounding factors. Instead, intrapartum variables such as unfavorable Bishop score and induction of labor played a more significant role in determining the mode of delivery.

Importantly, borderline AFI was identified as an independent predictor of low birth weight, suggesting an underlying association with placental insufficiency and fetal growth compromise. Subgroup analysis further revealed a progressive increase in adverse outcomes with decreasing AFI values within the borderline range, indicating that lower AFI values (5.1-6 cm) carry a higher risk.

These findings highlight that borderline AFI is not a uniform entity and should be considered a clinically relevant risk marker rather than a benign variation. However, routine aggressive intervention may not be justified solely on the basis of AFI. Individualized management with close fetal surveillance and judicious decision-making regarding induction of labor is essential to optimize maternal and perinatal outcomes.

Further large-scale, multicentric studies are recommended to validate these findings and refine management guidelines for borderline AFI at term.

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