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Mean Arterial Pressure in Early Pregnancy as A Predictor of Pre-Eclampsia: A Prospective Observational Study

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Abstract

Background: Pre-eclampsia (PE) remains a leading cause of maternal and perinatal morbidity and mortality, particularly in low-resource settings. Mean arterial pressure (MAP) is a simple, low-cost physiological measure that may aid early prediction. This study aimed to determine the role of first-trimester MAP in predicting subsequent development of pre-eclampsia.

Methods: This prospective observational study enrolled 134 pregnant women with singleton pregnancies at 11–14 weeks of gestation. MAP was measured using a standardized automated device. Women were categorized into Group A (MAP >90 mmHg, n=30) and Group B (MAP ≤90 mmHg, n=104). All participants were followed at 19–21, 27–29, and 37–39 weeks. The primary outcome was development of pre-eclampsia/eclampsia**.**

Results: The incidence of pre-eclampsia/eclampsia was 16.4% (22/134). Women with MAP >90 mmHg had significantly higher rates of PE (43.3% vs. 8.7%; OR=10.38, 95% CI=3.62–29.77; p<0.001). The sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy of MAP >90 mmHg for predicting PE were 43.3%, 91.3%, 59.1%, 84.8%, and 80.6%, respectively (Cohen's κ=0.383, fair agreement).

Conclusion: First-trimester MAP >90 mmHg demonstrates high specificity and fair predictive accuracy for pre-eclampsia, making it a valuable screening tool in resource-limited settings, though it should be used alongside other risk factors

Keywords: First trimester, low-resource settings, mean arterial pressure, prediction, pre-eclampsia.

Introduction

Pre-eclampsia (PE) is a hypertensive disorder of pregnancy affecting 5–15% of pregnancies globally and remains the third most common cause of maternal morbidity and mortality worldwide [1]. The World Health Organization reports that the incidence of PE is nearly seven times higher in developing countries like India (8–10% of all pregnancies) compared to developed nations [2]. PE is defined as new-onset hypertension (systolic ≥140 mmHg or diastolic ≥90 mmHg) with proteinuria or end-organ dysfunction after 20 weeks of gestation in a previously normotensive woman [1]. The condition is associated with serious maternal complications including convulsions, abruptio placentae, acute renal failure, cerebrovascular events, and long-term cardiovascular risks, as well as significant perinatal morbidity including prematurity and growth restriction [3,4].

Despite advances in obstetric care, early prediction of PE remains challenging, particularly in resource-limited settings where advanced biochemical markers (placental growth factor, PAPP-A) and Doppler

studies are unavailable [5]. Mean arterial pressure (MAP), calculated as diastolic pressure plus one-third of pulse pressure, is a simple, reproducible, low-cost physiological measure that integrates systolic and diastolic pressures. Systematic reviews have shown that first-trimester MAP has moderate discriminatory ability for subsequent PE, with area under the curve values ranging from 0.7–0.8 [6]. However, the predictive value depends critically on standardized measurement protocols [7]. The present study was planned to determine the role of early pregnancy MAP as a predictor of pre-eclampsia, with particular relevance to low-resource settings where simple screening tools are urgently needed.

Materials And Methods

This prospective observational study was conducted at the Department of Obstetrics & Gynaecology, Dr KNS Memorial Institute of Medical Sciences, Barabanki, over 24 months. The study adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for reporting observational research. The study protocol, data collection tools, consent forms, and patient information sheets were reviewed and approved by the Institutional Ethics Committee of Dr KNS Memorial Institute of Medical Sciences, Barabanki. Written informed consent was obtained from all participants after detailed explanation of the study procedures in the local language. Patient confidentiality was maintained throughout using unique patient identifiers.

Inclusion criteria were: (1) antenatal women with singleton pregnancies between 11–14 weeks of gestation; and (2) consent to participate. Cases of Chronic hypertension, use of antihypertensive medication, diabetes mellitus, nephropathy, autoimmune disorders (systemic lupus erythematosus, antiphospholipid syndrome), sickle cell disease, fetal abnormalities, previous cervical surgery or cerclage, history of three or more abortions, HIV infection, sustained corticosteroid use, aspirin therapy, calcium supplementation >1 g/day, fish oil intake >2.7 g/day, vitamin C >1000 mg/day, vitamin E >400 IU/day, and heparin therapy were excluded from the study.

Sample size was calculated using the formula $n = [Z^2P(1-P)]/d^2$, where Z=1.96 (95% confidence interval), P=50% (population proportion), and d=9% (margin of error), yielding 119 participants. A total of 134 consecutive eligible women were enrolled using simple random sampling.

MAP was measured using a standardized automated blood pressure device (appropriate cuff size based on mid-arm circumference) with participants seated comfortably, arm supported at heart level, after 5 minutes of rest [7]. Measurements were taken at 11–14 weeks (baseline), 19–21 weeks, 27–29 weeks, and 37–39 weeks. The average of three readings was recorded. MAP was also calculated using the formula: MAP = DBP + ⅓ (SBP – DBP). Women were categorized into Group A (MAP >90 mmHg, n=30) and Group B (MAP ≤90 mmHg, n=104) based on baseline measurement [8]. The primary outcome was development of pre-eclampsia/eclampsia, diagnosed according to ACOG 2020 criteria [9]: blood pressure ≥140/90 mmHg on two occasions ≥4 hours apart after 20 weeks with proteinuria (≥300 mg/24 hours, protein/creatinine ratio ≥0.3, or dipstick ≥2+) or end-organ dysfunction.

Data were analysed using IBM SPSS. Categorical variables were compared using chi-square test; continuous variables using independent t-test. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated. Cohen's kappa assessed agreement. $P<0.05$ was considered significant.

Results

A total of 134 pregnant women were enrolled and divided based on early pregnancy MAP. Group A (MAP >90 mmHg) included 30 women (22.4%), while Group B (MAP ≤90 mmHg) included 104 women (77.6%) (table 1 and figure 1). The mean age of the study population was 27.90 ± 6.28 years, with no significant difference between Group A (27.80 ± 6.07 years) and Group B (27.93 ± 6.37 years) ($p = 0.919$).

Baseline anthropometric and obstetric characteristics were comparable between groups. Mean BMI was 26.74 ± 5.33 kg/m² in Group A and 25.93 ± 5.69 kg/m² in Group B ($p = 0.485$). Nulliparous women numbered 8/30 in Group A versus 32/104 in Group B ($p = 0.513$). Overweight/obese participants (BMI ≥25 kg/m²) were 19/30 in Group A and 57/104 in Group B ($p = 0.550$). Overall, no significant intergroup differences were observed in baseline characteristics, confirming comparability between the study groups.

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To evaluate the hemodynamic progression throughout pregnancy, mean arterial pressure was tracked longitudinally across three predefined gestational windows (table 2 and figure 2) following the baseline first-trimester assessment: mid-gestation (19–21 weeks), early third trimester (27–29 weeks), and late third trimester (37–39 weeks).

The longitudinal data revealed two prominent clinical patterns:

- **Persistent Baseline Disparity:** Group A (baseline first-trimester MAP > 90mmHg) maintained significantly higher mean MAP values compared to Group B (MAP ≤ 90 mmHg) at every single follow-up time point ($p \leq 0.001$ for all comparisons).
- **Parallel Incremental Trends:** Both patient cohorts exhibited a steady, progressive increase in mean MAP values as gestational age advanced from the second trimester through to term.

At the 19–21 weeks assessment, the mean MAP in Group A was 92.77 ± 5.24 mmHg, whereas Group B demonstrated a noticeably lower mean MAP of 88.88 ± 5.13mmHg. This variation was highly statistically significant ($p < 0.001$), confirming that the hemodynamic gap identified in the first trimester persisted into mid-gestation.

By the early third trimester (27–29 weeks), both groups showed an upward shift in pressures. Group A's mean MAP rose to 96.03 ± 6.30 mmHg, while Group B's shifted to 90.46 ± 6.14 mmHg. The mathematical divergence between the two cohorts remained stark and highly significant ($p < 0.001$).

At the final longitudinal assessment prior to delivery (37–39 weeks), the mean MAP peaked in both groups. Group A reached a mean value of 98.86 ± 9.46 mmHg. Group B climbed to a mean value of 93.83 ± 6.13 mmHg. Despite the wider standard deviation in Group A at term, reflecting the acute onset of severe hypertensive variants or eclampsia in certain patients, the difference between the two cohorts remained highly significant ($p = 0.001$).

This continuous tracking indicates that an elevated first-trimester MAP is not a transient physiological spike, but rather an early marker of a sustained, high-pressure hemodynamic trajectory that continues throughout the course of pregnancy.

The overall incidence of pre-eclampsia/eclampsia in the study population was 16.4% (22/134) as demonstrated in table 3. A significantly higher proportion of women in Group A (MAP >90 mmHg) developed pre-eclampsia compared with Group B (MAP ≤90 mmHg) [13/30 (43.3%) vs. 9/104 (8.7%); $p<0.001$]. Women with elevated early pregnancy MAP had more than tenfold higher odds of developing pre-eclampsia than those with MAP ≤90 mmHg (OR=10.38; 95% CI=3.62–29.77), highlighting the strong predictive value of increased MAP for subsequent hypertensive disorders of pregnancy.

Analysis of disease severity further demonstrated an increased burden of adverse outcomes among women with elevated MAP. Non-severe pre-eclampsia was observed in 8 (26.7%) women in Group A compared to 5 (4.8%) in Group B. Similarly, severe pre-eclampsia occurred more frequently in Group A [3 (10.0%) vs. 4 (3.8%)], while eclampsia was reported exclusively among women with MAP >90 mmHg [2 (6.7%) vs. 0 (0.0%)]. These findings indicate that higher early pregnancy MAP is associated not only with an increased risk of pre-eclampsia but also with greater disease severity and progression to eclampsia ($p<0.001$).

Dipstick proteinuria assessment revealed as shown in table 4 significant differences between the two study groups ($p<0.001$). Women in Group A (MAP >90 mmHg) demonstrated markedly higher grades of proteinuria compared with those in Group B (MAP ≤90 mmHg). Specifically, 2+ proteinuria was observed in 6 of 30 women (20.0%) in Group A compared with 4 of 104 women (3.8%) in Group B, while 3+ proteinuria was present in 7 of 30 women (23.3%) versus 5 of 104 women (4.8%), respectively. These findings indicate a greater degree of renal involvement among women with elevated early pregnancy MAP, further supporting the association between increased MAP and the development of hypertensive disorders of pregnancy.

Adverse pregnancy outcomes, including preterm delivery, gestational diabetes mellitus, and fetal growth restriction, were also more frequent among women with MAP >90 mmHg. Such complications occurred in 11 of 30 women (36.7%) in Group A compared with 27 of 104 women (26.0%) in Group B. Although this difference did not reach statistical significance, the higher incidence observed in Group

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A suggests a trend toward poorer maternal and fetal outcomes among women with elevated early gestational MAP.

The diagnostic performance of first-trimester MAP >90 mmHg for predicting pre-eclampsia is summarized in Table 4. The test demonstrated a sensitivity of 43.3% (95% CI: 25.6–61.0%) and a high specificity of 91.3% (95% CI: 85.9–96.7%). The positive predictive value was 59.1% (95% CI: 38.6–79.6%), indicating that more than half of women with MAP >90 mmHg subsequently developed pre-eclampsia. Conversely, the negative predictive value was 84.8% (95% CI: 78.2–91.4%), suggesting that women with MAP ≤90 mmHg were unlikely to develop the condition. Overall diagnostic accuracy was 80.6% (95% CI: 73.9–87.3%).

Furthermore, agreement analysis demonstrated a Cohen's kappa coefficient of 0.383 ($p<0.05$), indicating fair agreement between elevated first-trimester MAP and the subsequent occurrence of pre-eclampsia. Taken together, these findings suggest that while MAP >90 mmHg has moderate sensitivity, its high specificity, good negative predictive value, and overall diagnostic accuracy make it a useful screening parameter for identifying pregnant women at increased risk of developing pre-eclampsia.

Discussion

This prospective study evaluated the role of first-trimester MAP in predicting pre-eclampsia among 134 pregnant women. The incidence of PE/eclampsia was 16.4%, which is consistent with the reported 8–10% incidence in India [2] and slightly higher than some studies due to the inclusion of eclampsia cases [10].

A key finding was the significant association between elevated first-trimester MAP (>90 mmHg) and subsequent development of PE (43.3% vs. 8.7%; OR=10.38). This aligns with previous research by Gasse et al., who reported that MAP >90 mmHg at 11–13 weeks predicted 51% of all PE cases [8], and Jasovic-Siveska et al., who found MAP to be a better predictor than isolated systolic or diastolic pressures [11]. The relative risks for non-severe PE, severe PE, and eclampsia in the high MAP group were 3.38, 2.02, and 4.71 respectively, demonstrating a dose-response relationship.

The diagnostic accuracy findings (sensitivity 43.3%, specificity 91.3%, accuracy 80.6%) are comparable to Udenze et al., who reported 45.5% sensitivity and 90% specificity at a cut-off of 88.33 mmHg [12]. The high specificity (91.3%) is particularly clinically valuable as it enables accurate identification of women who truly require intervention, reducing unnecessary prophylactic treatment. This is especially important in resource-limited settings where aspirin prophylaxis (150 mg daily) is recommended for high-risk women [13]. The fair agreement ($\kappa=0.383$) suggests that while MAP is useful, it should not be used as a standalone predictor.

Unlike some studies that combined MAP with other biomarkers [14,15,16], our study deliberately evaluated MAP alone to assess its independent predictive value—a pragmatic approach for low-resource settings where advanced testing is unavailable [5]. The lack of significant association between MAP and other pregnancy complications (preterm delivery, GDM, FGR) contrasts with larger studies [17,18], likely due to our smaller sample size.

The study has several limitations: small sample size, single-centre design, strict exclusion criteria limiting generalizability, and exclusion of other predictive markers (uterine artery Doppler, PlGF, PAPP-A) that could have enhanced predictive accuracy when combined with MAP [19,20,21].

Conclusion

First-trimester mean arterial pressure >90 mmHg is a significant predictor of pre-eclampsia, demonstrating high specificity (91.3%) and fair diagnostic accuracy (80.6%). It is a simple, low-cost, reproducible measure particularly valuable in low-resource settings where advanced biomarkers are unavailable. Women with elevated early pregnancy MAP should be categorized as high-risk and receive enhanced surveillance and prophylactic aspirin where indicated. However, MAP should be used as part of a multivariable screening approach incorporating maternal history and other risk factors rather than as a standalone test. Larger multicentric studies are recommended to validate these findings and develop integrated prediction models.

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Tables

Table 1: Baseline characteristics of study groups

Characteristic	Group A (MAP>90) (N=30)	Group B (MAP≤90) (N=104)	P-Value
Age (years), mean±SD	27.80±6.07	27.93±6.37	0.919
BMI (kg/m²), mean±SD	26.74±5.33	25.93±5.69	0.485
Nullipara, n(%)	8 (26.7)	32 (30.8)	0.513
Overweight/Obese (BMI≥25), n(%)	19 (63.3)	57 (54.8)	0.550

Table 2: Comparison of MAP at different gestational ages

Gestational age	Group A (n=30)	Group B (n=104)	P-value
19-21 weeks	92.77±5.24	88.88±5.13	<0.001
27-29 weeks	96.03±6.30	90.46±6.14	<0.001
37-39 weeks	98.86±9.46	93.83±6.13	0.001

Values are mean±SD mmHg

Table 3: Prevalence and severity of pre-eclampsia

Outcome	Group A (n=30)	Group B (n=104)	Total (N=134)	P-Value
Pre-eclampsia, n (%)	13 (43.3)	9 (8.7)	22 (16.4)	<0.001
Non-severe PE	8 (26.7)	5 (4.8)	13 (9.7)	
Severe PE	3 (10.0)	4 (3.8)	7 (5.2)	
Eclampsia	2 (6.7)	0 (0.0)	2 (1.5)	

Table 4: Diagnostic accuracy of first-trimester MAP >90 mmHg for predicting pre-eclampsia

Parameter	Value	95% CI
Sensitivity	43.3%	25.6-61.0%
Specificity	91.3%	85.9-96.7%
Positive Predictive Value	59.1%	38.6-79.6%
Negative Predictive Value	84.8%	78.2-91.4%
Diagnostic Accuracy	80.6%	73.9-87.3%

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Cohen's Kappa	0.383	p<0.05

Figures

Figure 1 Baseline characteristics of study groups

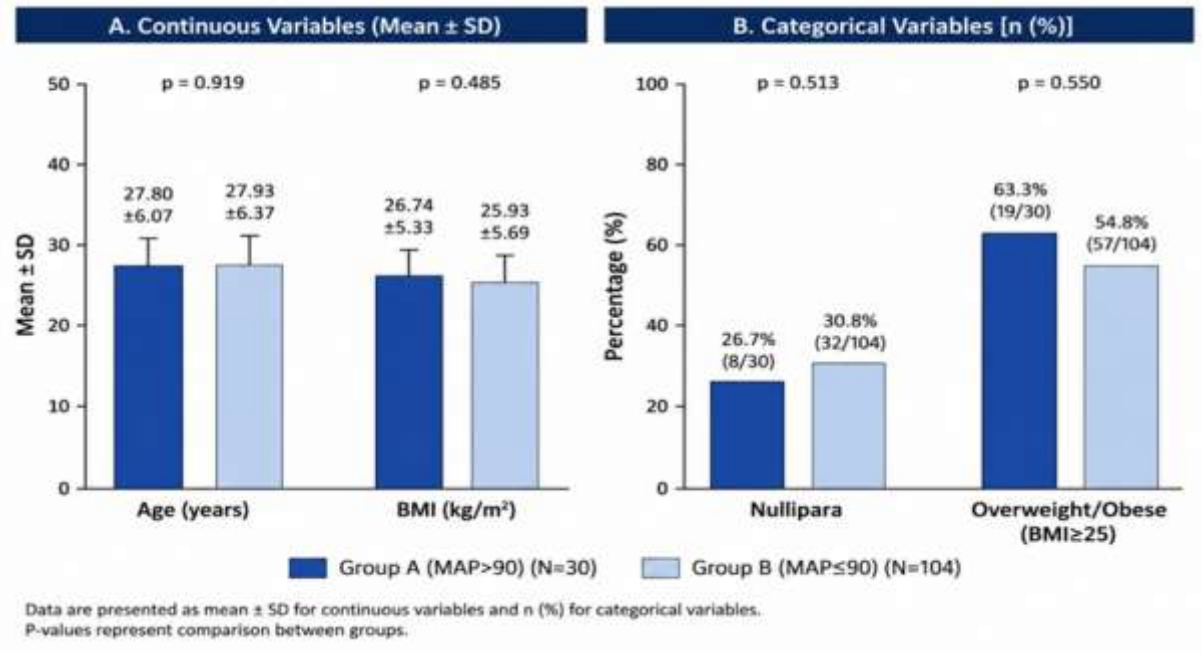
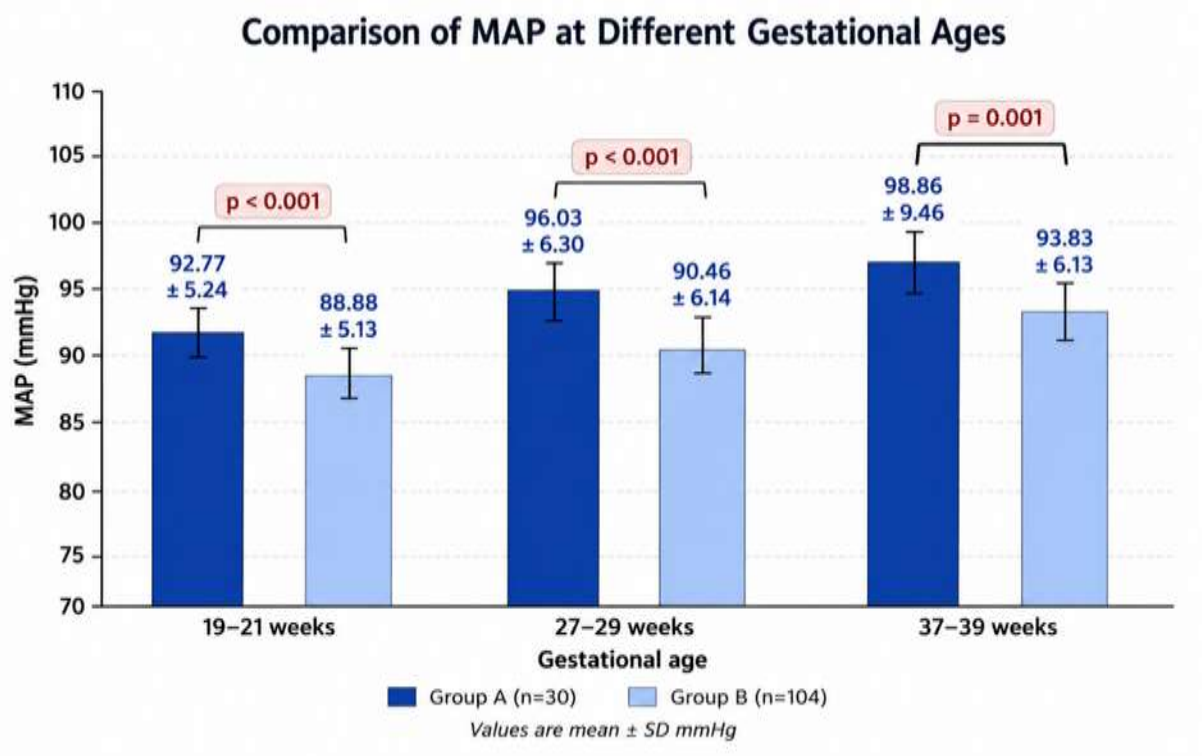


Figure 2 Comparison of MAP at different gestational ages



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