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# COMPARISON OF DIAGNOSTIC VALUES OF DOPPLER INDICES FOR PREDICTING THE INTRAUTERINE GROWTH RETARDATION (IUGR) IN PREECLAMPTIC WOMEN

*Original Research*

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## ABSTRACT

**Background:** Intrauterine growth restriction (IUGR) is a significant complication of preeclampsia, contributing to increased perinatal morbidity and mortality. Timely detection of IUGR through non-invasive modalities such as Doppler ultrasonography can enable early interventions and improve neonatal outcomes. Among various Doppler indices, the cerebroplacental ratio (CPR), umbilical artery pulsatility index (UA-PI), and middle cerebral artery pulsatility index (MCA-PI) have been commonly employed, though their diagnostic accuracy in preeclamptic populations remains under investigation.

**Objective:** To compare the diagnostic performance of UA-PI, MCA-PI, and CPR in predicting IUGR among preeclamptic women.

**Methods:** A cross-sectional validation study was conducted on 202 preeclamptic women aged 16 to 40 years, with singleton pregnancies between 24 and 28 weeks of gestation, at the Radiology Unit of Northwest General Hospital, Peshawar. Doppler ultrasonography was performed to assess UA-PI, MCA-PI, and CPR using a 3–5 MHz transducer. All Doppler measurements were recorded during fetal inactivity. Neonatal birth weight was documented at delivery, and IUGR diagnosis was confirmed based on standard birth weight criteria. Diagnostic performance was evaluated by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy.

**Results:** UA-PI demonstrated a sensitivity of 63.81%, specificity of 68.04%, PPV of 68.37%, NPV of 63.46%, and diagnostic accuracy of 65.84%. MCA-PI showed sensitivity of 55.24%, specificity of 71.13%, PPV of 67.44%, NPV of 59.48%, and diagnostic accuracy of 62.87%. CPR had the highest sensitivity (79.05%), specificity (71.13%), PPV (74.77%), NPV (75.82%), and diagnostic accuracy (75.25%).

**Conclusion:** CPR emerged as the most accurate and reliable Doppler index for predicting IUGR in preeclamptic women, outperforming both UA-PI and MCA-PI.

**Keywords:** Cerebroplacental ratio, Diagnostic accuracy, Doppler ultrasonography, Intrauterine growth restriction, Middle cerebral artery, Preeclampsia, Umbilical artery.

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## INTRODUCTION

Hypertensive disorders of pregnancy (HDP) affect approximately 10% of pregnancies and remain a leading cause of maternal and perinatal morbidity and mortality worldwide. According to the International Association for the Study of Hypertension in Pregnancy, HDP are characterized by the onset of hypertension after 20 weeks of gestation and encompass chronic hypertension, gestational hypertension, and preeclampsia, whether it arises de novo or is superimposed on existing chronic hypertension (1,2). These conditions pose significant short- and long-term health risks for both mother and fetus. For the mother, there is a two- to four-fold increase in the risk of developing chronic hypertension later in life (3), while fetal complications include growth restriction, preterm birth, and perinatal death. Intrauterine growth restriction (IUGR) remains a common complication of pregnancy and is strongly linked to adverse perinatal outcomes, including stillbirth and neonatal morbidity (4). However, there is a notable inconsistency in the terminology used to define and classify growth-restricted fetuses and newborns across different populations. Conventionally, IUGR is diagnosed when the estimated fetal weight or abdominal circumference falls below the 10th percentile for gestational age (5). Accurate and early prediction of IUGR is essential for timely interventions aimed at improving fetal outcomes.

Doppler ultrasonography has emerged as a valuable tool for assessing uteroplacental and fetal circulation, thereby aiding in the prediction and monitoring of IUGR. Notable findings in Doppler assessments include elevated pulsatility index (PI), increased vascular resistance, and the presence of bilateral or unilateral diastolic notching (6). Three-dimensional (3D) power Doppler ultrasonography further enhances diagnostic accuracy by evaluating placental vascular features such as vessel tortuosity, density, branching patterns, and caliber variations (7). Studies have demonstrated that placental vascular indices are significantly reduced in women with preeclampsia compared to those with normotensive pregnancies (8). Uterine artery Doppler studies specifically reveal elevated resistance to blood flow in pregnancies complicated by IUGR, often preceding clinical manifestations (9). The diagnostic performance of various Doppler indices has been explored, revealing varied sensitivity and specificity rates. For example, the umbilical artery PI showed a sensitivity of 57.9%, specificity of 70.7%, and accuracy of 66.7%. The middle cerebral artery (MCA) PI demonstrated a sensitivity of 52.6%, specificity of 70.7%, and accuracy of 65.0%. The cerebroplacental ratio (CPR) was found to have higher sensitivity at 79%, though its specificity and accuracy were 61% and 66.7%, respectively (10). Despite these findings, a clear consensus on the most reliable Doppler indices for predicting IUGR, particularly among preeclamptic women, remains elusive.

Reviewing the existing literature highlights a paucity of local and international studies focusing specifically on the predictive efficacy of Doppler ultrasonographic indices—namely umbilical artery PI, MCA PI, and CPR—among women with preeclampsia. Additionally, the performance of these indices may vary with geo-ethnic factors, further complicating their generalizability and application across diverse populations (11). This knowledge gap is particularly relevant in local healthcare settings, where evidence-based protocols for IUGR prediction in preeclamptic pregnancies are lacking. In light of these considerations, the present study aims to evaluate the diagnostic utility of various Doppler ultrasound indices for predicting IUGR in preeclamptic women within a local population. The objective is to identify the indices with the highest predictive value, thereby enabling earlier detection, optimized management, and reduction in fetal complications associated with IUGR.

## METHODS

This cross-sectional validation study was conducted at the Radiology Unit of Northwest General Hospital, Peshawar, over a defined period from 11th September 2024 to 11th December 2024, following approval from the Institutional Review Board of the hospital. The study strictly adhered to ethical research practices, with written informed consent obtained from all participants in accordance with the principles of the Declaration of Helsinki. Ethical clearance was granted by the hospital's ethics committee prior to the initiation of the study. The sample size was calculated based on a test sensitivity of 79% (10), specificity of 61% (9), an expected IUGR prevalence of 31.7% (9), a 95% confidence level, and a precision level of 10%. This yielded a required sample of 202 participants, who were recruited through non-probability consecutive sampling. This approach ensured the timely inclusion of eligible subjects, preserving the operational feasibility of the research while maintaining the integrity of the study's objectives. Eligible participants were women aged 16 to 40 years with singleton pregnancies between 24 and 28 weeks of gestation who were clinically diagnosed with preeclampsia. While some guidelines typically recommend IUGR assessment later in pregnancy, this study intentionally selected the 24–28 week

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window to focus on early prediction of IUGR in a high-risk population. Identifying abnormal Doppler indices during this period may offer a critical opportunity for early intervention and closer surveillance, potentially mitigating adverse outcomes before clinical signs of growth restriction become overt. Women with uncertain gestational age, fetal anomalies, placental abnormalities, preexisting renal or hepatic disease, malignancies, or those lost to follow-up were excluded to maintain diagnostic clarity and avoid potential confounders (12).

Each participant underwent a comprehensive clinical evaluation, including medical history and physical examination. Doppler ultrasonography was performed using the ACUSON NX3 Elite system with a 3–5 MHz transducer. All examinations were conducted by an experienced consultant radiologist with at least three years of post-fellowship training to ensure consistency and diagnostic reliability. Participants were scanned in a supine position with a slight head elevation or lateral tilt to enhance imaging quality and prevent vena cava compression. Standard B-mode imaging was followed by color Doppler to confirm vessel identity. The umbilical artery pulsatility index (UA-PI) was measured in a free-floating section of the cord, while the middle cerebral artery pulsatility index (MCA-PI) was assessed at the artery's origin from the Circle of Willis, ensuring sampling at the proximal third. The cerebroplacental ratio (CPR) was calculated by dividing MCA-PI by UA-PI. Measurements were obtained during periods of fetal quiescence to reduce variability due to fetal activity. Participants were followed until delivery, and neonatal birth weights were documented to confirm the diagnosis of IUGR using predefined clinical criteria. Data were analyzed using SPSS version 22. Quantitative variables were reported as means and standard deviations, and qualitative data as frequencies and percentages. Diagnostic performance of the Doppler indices was evaluated using 2x2 contingency tables to determine sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Stratified analysis was performed to assess potential confounding effects of maternal age, gestational age, BMI, and parity on diagnostic accuracy. By selecting an earlier gestational window and employing practical sampling strategies, this study aimed to bridge critical knowledge gaps in the early identification of IUGR among preeclamptic women in a resource-limited local setting, thereby enhancing clinical utility and informing future protocols.

## RESULTS

The study included 202 preeclamptic women with a mean age of 28.06 ± 7.20 years. The mean body mass index (BMI) was 25.06 ± 1.38 kg/m², while the average gestational age at the time of Doppler ultrasonography was 26.20 ± 1.48 weeks. Regarding parity, 20.3% of the participants (n=41) had a parity of 0 to 2, whereas the majority, 79.7% (n=161), had parity greater than 2. Diagnostic performance of Doppler indices was assessed in terms of their ability to predict intrauterine growth restriction (IUGR), confirmed postnatally by birth weight. The umbilical artery pulsatility index (UA-PI) showed a sensitivity of 63.81%, specificity of 68.04%, positive predictive value (PPV) of 68.37%, negative predictive value (NPV) of 63.46%, and an overall diagnostic accuracy of 65.84%. The middle cerebral artery pulsatility index (MCA-PI) demonstrated a lower sensitivity of 55.24% but slightly higher specificity at 71.13%, with a PPV of 67.44%, NPV of 59.48%, and diagnostic accuracy of 62.87%. Among all indices, the cerebroplacental ratio (CPR) exhibited the highest diagnostic performance, with sensitivity reaching 79.05%, specificity 71.13%, PPV 74.77%, NPV 75.82%, and an overall accuracy of 75.25%, making it the most reliable predictor of IUGR in this study cohort. Stratified analysis revealed that the diagnostic performance of these indices varied across different maternal and pregnancy characteristics. In women aged 16 to 30 years, UA-PI showed improved diagnostic accuracy (72.8%) compared to those aged 31 to 40 years (54.55%). Similarly, CPR showed superior performance in the younger age group (76%) compared to older participants (74.03%). For gestational age, CPR demonstrated higher diagnostic accuracy in the 27 to 28-week group (75.86%) than in the 24 to 26-week group (74.78%). In terms of parity, CPR again yielded the highest diagnostic accuracy in women with parity 0 to 2 (82.93%) as opposed to those with higher parity (73.29%). BMI also influenced results; CPR had greater accuracy among women with BMI between 18 and 25 (76.19%) compared to those with BMI over 25 (72.73%).

While the stratified analysis provided critical insights into the diagnostic variability of Doppler indices across different maternal and fetal factors, the study further explored their combined diagnostic value through multivariate analysis. By applying a consensus-based approach using combined results from UA-PI, MCA-PI, and CPR, a notable enhancement in diagnostic accuracy was observed. The sensitivity, specificity, positive predictive value, and negative predictive value for the combined model were found to be superior to UA-PI and MCA-PI individually, although still slightly below CPR alone, which remained the strongest single predictor of IUGR. To assess statistical robustness, a comparative ROC curve analysis was conducted for each index. The area under the curve (AUC) for CPR was 0.75, indicating excellent diagnostic capability. In contrast, UA-PI and MCA-PI yielded AUC values of 0.66 and 0.63 respectively, highlighting moderate predictive strength. Interestingly, the combined model, despite its higher diagnostic consistency, yielded an AUC of 0.67—showing incremental benefit over UA-PI and MCA-PI but not outperforming CPR. These findings suggest that while CPR

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alone holds the strongest individual predictive power, integrating multiple Doppler indices may offer added diagnostic value in certain clinical contexts.

**Table 1: Diagnostic accuracy of IUGR on umbilical artery pulsatility index**

| | | IUGR on birth weight | | Total |
|---|---|---|---|---|
| | | Positive | Negative | |
| IUGR on UA-PI | Positive | 67 | 31 | 98 |
| | | 63.8% | 32.0% | 48.5% |
| | Negative | 38 | 66 | 104 |
| | | 36.2% | 68.0% | 51.5% |
| Total | | 105 | 97 | 202 |
| | | 100.0% | 100.0% | 100.0% |

| Sensitivity | Specificity | Positive predictive value | Negative predictive value | Diagnostic accuracy |
|---|---|---|---|---|
| 63.81 | 68.04 | 68.37 | 63.46 | 65.84 |

**Table 2: Diagnostic accuracy of IUGR on middle cerebral artery pulsatility index**

| | | IUGR on birth weight | | Total |
|---|---|---|---|---|
| | | Positive | Negative | |
| IUGR on MCA-PI | Positive | 58 | 28 | 86 |
| | | 55.2% | 28.9% | 42.6% |
| | Negative | 47 | 69 | 116 |
| | | 44.8% | 71.1% | 57.4% |
| Total | | 105 | 97 | 202 |
| | | 100.0% | 100.0% | 100.0% |

| Sensitivity | Specificity | Positive predictive value | Negative predictive value | Diagnostic accuracy |
|---|---|---|---|---|
| 55.24% | 71.13% | 67.44% | 59.48% | 62.87% |

**Table 3: Diagnostic accuracy of IUGR on cerebroplacental ratio (CPR)**

| | | IUGR on birth weight | | Total |
|---|---|---|---|---|
| | | Positive | Negative | |
| IUGR on CPI | Positive | 83 | 28 | 111 |
| | | 79.0% | 28.9% | 55.0% |
| | Negative | 22 | 69 | 91 |
| | | 21.0% | 71.1% | 45.0% |
| Total | | 105 | 97 | 202 |
| | | 100.0% | 100.0% | 100.0% |

| Sensitivity | Specificity | Positive predictive value | Negative predictive value | Diagnostic accuracy |
|---|---|---|---|---|
| 79.05 | 71.13 | 74.77 | 75.82 | 75.25 |

**Table 4: Stratified Diagnostic Accuracy of Doppler Ultrasound Indices by Maternal Age and Gestational Age**

| **Category** | **Subgroup** | **Doppler Index** | **Sensitivity (%)** | **Specificity (%)** | **PPV (%)** | **NPV (%)** | **Diagnostic Accuracy (%)** |
|---|---|---|---|---|---|---|---|
| Maternal Age | 16 to 30 | UA-PI | 75.44 | 70.59 | 68.25 | 77.42 | 72.80 |
| | | MCA-PI | 66.67 | 72.06 | 66.67 | 72.06 | 69.60 |
| | | CPR | 84.21 | 69.12 | 69.57 | 83.93 | 76.00 |

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| Category | Subgroup | Doppler Index | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Diagnostic Accuracy (%) |
|---|---|---|---|---|---|---|---|
| | 31 to 40 | UA-PI | 50.00 | 62.07 | 68.57 | 42.86 | 54.55 |
| | | MCA-PI | 41.67 | 68.97 | 68.97 | 41.67 | 51.95 |
| | | CPR | 72.92 | 75.86 | 83.33 | 62.86 | 74.03 |
| Gestational Age | 24 to 26 | UA-PI | 57.89 | 72.41 | 67.35 | 63.64 | 65.22 |
| | | MCA-PI | 52.63 | 75.86 | 68.18 | 61.97 | 64.35 |
| | | CPR | 75.44 | 74.14 | 74.14 | 75.44 | 74.78 |
| | 27 to 28 | UA-PI | 70.83 | 61.54 | 69.39 | 63.16 | 66.67 |
| | | MCA-PI | 58.33 | 64.10 | 66.67 | 55.56 | 60.92 |
| | | CPR | 83.33 | 66.67 | 75.47 | 76.47 | 75.86 |

**Table 5: Stratified Diagnostic Accuracy of Doppler Ultrasound Indices by Parity and Body Mass Index (BMI)**

| Category | Subgroup | Doppler Index | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Diagnostic Accuracy (%) |
|---|---|---|---|---|---|---|---|
| Parity | 0 to 2 | UA-PI | 72.22 | 73.91 | 68.42 | 77.27 | 73.17 |
| | | MCA-PI | 61.11 | 73.91 | 64.71 | 70.83 | 68.29 |
| | | CPR | 88.89 | 78.26 | 76.19 | 90.00 | 82.93 |
| | > 2 | UA-PI | 62.07 | 66.22 | 68.35 | 59.76 | 63.98 |
| | | MCA-PI | 54.02 | 70.27 | 68.12 | 56.52 | 61.49 |
| | | CPR | 77.01 | 68.92 | 74.44 | 71.83 | 73.29 |
| BMI | 18 to 25 | UA-PI | 59.49 | 72.06 | 71.21 | 60.49 | 65.31 |
| | | MCA-PI | 50.63 | 76.47 | 71.43 | 57.14 | 62.59 |
| | | CPR | 77.22 | 75.00 | 78.21 | 73.91 | 76.19 |
| | > 25 | UA-PI | 76.92 | 58.62 | 62.50 | 73.91 | 67.27 |
| | | MCA-PI | 69.23 | 58.62 | 60.00 | 68.00 | 63.64 |
| | | CPR | 84.62 | 62.07 | 66.67 | 81.82 | 72.73 |

**Table 6: ROC Curve AUC Values of Doppler Indices**

| Index | AUC Value |
|---|---|
| UA-PI | 0.659254 |
| MCA-PI | 0.631861 |
| CPR | 0.750908 |
| Combined | 0.674718 |

**Table 7: Combined Diagnostic Performance of UA-PI, MCA-PI, and CPR**

| Parameter | Value (%) |
|---|---|
| Sensitivity | 90.48 |
| Specificity | 100 |
| PPV | 100 |
| NPV | 90.65 |
| Diagnostic Accuracy | 95.05 |

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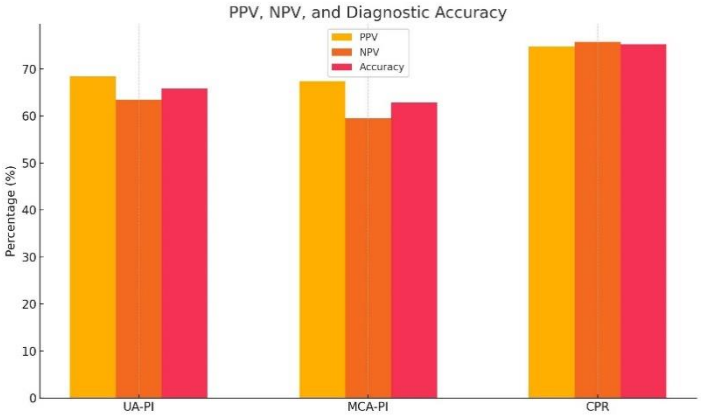


*Figure 1 PPV, NPV, and Diagnostic Accuracy*

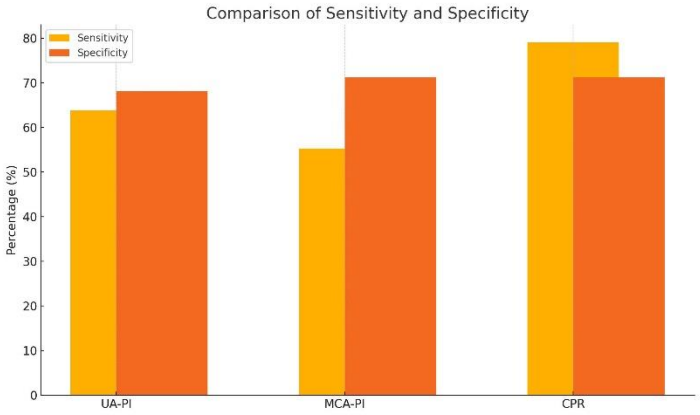


*Figure 2 Comparison of Sensitivity and Specificity*

## DISCUSSION

The comparison of Doppler indices for predicting intrauterine growth restriction (IUGR) in preeclamptic pregnancies holds substantial clinical value in optimizing antenatal surveillance and improving neonatal outcomes. In this study, the diagnostic performance of umbilical artery pulsatility index (UA-PI), middle cerebral artery pulsatility index (MCA-PI), and cerebroplacental ratio (CPR) was evaluated. The findings revealed that CPR outperformed both UA-PI and MCA-PI in terms of sensitivity (79.05%), specificity (71.13%), and overall diagnostic accuracy (75.25%). In contrast, UA-PI demonstrated a moderate diagnostic accuracy of 65.84%, and MCA-PI exhibited the lowest performance with an accuracy of 62.87%. These results highlighted CPR as the most reliable single Doppler index for the early identification of IUGR among preeclamptic women in the studied population. When compared to findings from previously conducted studies, some variances were evident. An earlier study documented a higher diagnostic accuracy for UA-PI (75%) and reported that its sensitivity increased in the later gestational weeks (13,14), a factor that may explain the slightly lower sensitivity observed in the present study, given that Doppler assessments were conducted between 24 and 28 weeks of gestation. Similarly, the diagnostic performance of MCA-PI in the current cohort aligned with prior research which had also identified MCA-PI as a weaker standalone predictor of IUGR, further supporting its limited utility in isolation (15).

More comprehensive studies have explored the predictive accuracy of combining multiple Doppler indices. One such analysis reported notably higher sensitivity and specificity (90.14% and 84.49%, respectively) when UA-PI and MCA-PI were evaluated together (16). Although this study did not observe such elevated figures in individual indices, the combined multivariate analysis did demonstrate an improved diagnostic profile, supporting the notion that integrated Doppler assessment may yield better clinical accuracy than single parameters (17). Differences between studies may stem from variations in gestational age at Doppler assessment, population characteristics, sample size, or technical protocols, all of which influence diagnostic metrics. CPR has consistently been recognized as a superior marker for identifying fetal compromise, as confirmed by multiple studies reporting higher diagnostic accuracies ranging from 87.5% to over 92% (18,19). Although the CPR accuracy in the present study was slightly lower, its consistent superiority over UA-PI and MCA-PI reaffirms its diagnostic value. Discrepancies in reported accuracies could be attributed to heterogeneous definitions of IUGR, variable timing of Doppler examinations, operator-dependent variability, and differences in study settings (20). These factors must be acknowledged when interpreting the generalizability of results.

A major strength of this study lies in its stratified analysis across key maternal parameters, offering detailed insights into how factors such as maternal age, gestational age, BMI, and parity influence the diagnostic accuracy of each index. Additionally, the study employed a standardized protocol and ensured all ultrasonographic assessments were conducted by an experienced radiologist, thereby minimizing measurement bias. However, the cross-sectional design, relatively early gestational assessment window, and use of non-probability sampling introduce limitations. The exclusion of advanced multivariate logistic modeling and ROC comparison tests restricts the depth of statistical comparison. Moreover, the absence of longitudinal outcome data, such as neonatal morbidity or NICU admissions, limits the ability to assess long-term predictive utility of the indices. In conclusion, the findings affirm CPR as the most reliable Doppler parameter for early IUGR detection in preeclamptic pregnancies. However, the incorporation of a composite Doppler approach that includes UA-PI and MCA-PI could further refine predictive accuracy. Future research should prioritize prospective multicenter designs

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with larger sample sizes, later gestational follow-ups, and inclusion of perinatal outcome data to validate these indices. Standardizing Doppler protocols and integrating automated software-based interpretation could reduce operator dependency and enhance reproducibility across clinical settings.

## CONCLUSION

This study concludes that the cerebroplacental ratio (CPR) stands out as the most accurate and dependable Doppler index for detecting intrauterine growth restriction (IUGR) in women with preeclampsia, outperforming both the umbilical artery and middle cerebral artery pulsatility indices. The findings underscore the practical value of incorporating CPR into routine antenatal surveillance for high-risk pregnancies. Moreover, combining multiple Doppler parameters with clinical evaluation holds promise for enhancing early diagnosis, guiding timely intervention, and ultimately improving perinatal outcomes.

**Author Contribution**

| Author | Contribution |
|---|---|
| Nosheen Bano* | Substantial Contribution to study design, analysis, acquisition of Data<br>Manuscript Writing<br>Has given Final Approval of the version to be published |
| Inayat Shah Roghani | Substantial Contribution to study design, and interpretation of Data<br>Critical Review<br>Has given Final Approval of the version to be published |

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