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The Role of Doppler Ultrasonography in the Prediction of Fetal Outcome among Patients with Pregnancy Induced Hypertension (PIH): Review Article

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ABSTRACT

Background: Pregnancy-induced hypertension (PIH) is a major contributor to fetal & maternal mortality & morbidity worldwide. It increases the risk of complications like eclampsia, pre-eclampsia, fetal growth restriction, placental abruption & pre-term delivery. Early recognition & continuous monitoring of possible pregnancies are essential to improve results. Doppler ultrasonography has developed as a valuable non-invasive instrument in assessing uteroplacental & fetoplacental circulation, particularly in cases with PIH.

Objective: This article aimed to throw the light on the role of Doppler ultrasonography in the prediction of fetal outcome among patients with Pregnancy Induced Hypertension.

Methods: We used Google Scholar, Science Direct, PubMed, and other internet databases for Doppler ultrasonography, Pregnancy-induced hypertension, Uteroplacental circulation and Fetal outcome. Additionally, the writers combed through relevant literature for references, however they only included researches covering the years from 2002 to 2024. Due of lack of translation-related sources, documents in languages other than English were excluded. Also, works in progress, unpublished publications, abstracts from conferences, and dissertations that did not form part of broader scientific investigations were excluded.

Conclusion: Doppler evaluation of the uterine & umbilical arteries gives critical information about fetal adaptation & placental resistance. Abnormal results like enhanced resistance index (RI), absent or reversed flow during end-diastole in the umbilical artery, or a poor cerebroplacental ratio are strong predictors of adverse perinatal results, including intrauterine growth restriction (IUGR), decreased birth weight, oligohydramnios & perinatal mortality. The ability to detect these alterations enables clinicians to implement timely interventions, involving corticosteroids for fetal lung maturity and planning of early delivery if necessary. In addition, Doppler ultrasound is useful in predicting maternal complications like progression to severe preeclampsia or HELLP syndrome. Its role is particularly significant in resource-limited settings where access to more advanced fetal monitoring techniques may be unavailable. Overall, the integration of Doppler researches into the routine care of hypertensive pregnancies increases the possibility of improving maternal stratification & fetal prognosis by allowing for better clinical decision-making.

Keywords: Doppler ultrasonography, Pregnancy-induced hypertension, Uteroplacental circulation, Fetal outcome.

INTRODUCTION

Hypertension in pregnancy:

Hypertensive disorders in pregnancy (HDP) significantly contribute to fetal, maternal as well as neonatal mortality & morbidity, affecting around ten percent of pregnant women globally. This rate is expected to increase because of the increasing overweight and advancing age of women who conceive. Pregnant women with HDP are susceptible to stroke, thromboembolic events, pulmonary edema, placental abruption, intravascular coagulation syndrome, & several organ failures. The probabilities of fetal involvement include intrauterine growth preterm, restriction, & intrauterine demise. All those risks are especially enhanced in cases of pre-eclampsia. Neonates have an elevated possibility of preterm births with reduce birth weight, postnatal mortality, & extended high-level neonatal care [(1)].

The definition of hypertension in pregnancy:

Hypertension in pregnancy was always defined in a standardized way, but regarding the "National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy" the suggestion is presently a diastolic blood pressure (DBP) ⩾ ninety milligrams of mercury or/and a systolic blood pressure (SBP) ⩾ one hundred forty milligrams of mercury [(2)].

The severity of hypertension is as follows:

Non-severe hypertension:

Any significances among DBP 90–109 mmHg & SBP 140–159 mmHg. Sometimes this grouping as a whole is termed "mild," or it is further analyzed into moderate (150–159/100–109 mmHg) and mild (140–149/90–99 mmHg) [(3)].

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Severe hypertension: DBP ⩾ 110 mmHg and/or SBP ⩾ 160 mmHg. Severe hypertension during gestation has less thresholds than in non-pregnant individuals, as pregnancies are susceptible to hypertensive encephalopathy at reduced blood pressure levels [(4)].

Classification of hypertensive disorders of pregnancy

- **Chronic hypertension**

Chronic hypertension (CH) is characterized by a DBP of ninety mmHg or higher and/or the SBP of one hundred forty mmHg or greater, prior to gestation or before twenty weeks of pregnancy the utilization of antihypertensive drugs pre-gestation, or the continuation of hypertension beyond twelve weeks postpartum [(3)]. Approximately three to five percent of pregnant women are thought to be affected by chronic hypertension.

- **Gestational hypertension (GH)**

Gestational hypertension is characterized by a SBP of one hundred forty mmHg or greater and/or a DBP of ninety mmHg or greater following twenty weeks of gestation in a woman who had normal BP. A woman diagnosed with GH who exhibits a persistent postpartum rise in BP should be categorized as having CH [(5)].

- **Preeclampsia without and with severe features**

Preeclampsia is a hypertensive illness of gestation characterized by the new onset of proteinuria & hypertension, often appearing following twenty weeks of gestation [(5)]. According to ACOG, proteinuria is characterized by: (1) A twenty-four-hour urine sample containing three hundred milligrams or more of protein and (2) A protein to creatinine ratio of 0.3 milligrams per deciliter or higher or (3) a dipstick reading of 2+ in the absence of quantitative parameters. Nonetheless, preeclampsia may present without proteinuria & further diagnostic criteria that involve: (a) Thrombocytopenia, characterized by a platelet count below 100,000/10^9/liter, (b) Reduce kidney function, shown by transaminase levels over double the normal upper limit, (c) Severe pain in the upper right quadrant or epigastric area that is not correlated with alternative conditions, (d) Kidney failure characterized by serum creatinine exceeding 1.1 milligrams per deciliter or a doubling of serum creatinine levels in the nonexistent of other kidney pathologies, (e) A newly developed headache that remains unaffected by acetaminophen & does not align with any other diagnoses or visual symptoms and (f) Pulmonary edema.

PE with severe characteristics is characterized by a SBP of one hundred sixty mmHg or higher & a DBP of one hundred ten mmHg or higher on two separate occasions at least four hrs apart. The medical manifestation of hemolysis, enhanced hepatic enzyme levels, as well as a reduced platelet count (HELLP syndrome) is a form of PE with severe characteristics that commonly happens in the 3rd trimester & is correlated with enhanced maternal mortality & morbidity. The diagnostic criteria for HELLP involve: (a) Lactate dehydrogenase elevated to sixty IU/L or above, (b) Alanine and aspartate aminotransferase levels enhanced above double the normal upper limit, (c) Platelet count below 100,000 × 10^9/liter [(5)]. Nonetheless, the right upper quadrant generalized fatigue & pain are the primary presenting symptoms in ninety percent of patients.

- **Chronic hypertension with superimposed preeclampsia:** CH happens in one to five percent of Pregnancies & twenty to fifty percent of these women go on to advanced superimposed PE. A probability of superimposed PE in women with CH rises among those who are Black, smokers, obese, possess a DBP over hundred mmHg, have had CH for over four years & have a history of PE in previous pregnant women.

The frequency of superimposed PE is significantly elevated in women with end-organ breakdown or CH, nearing seventy-five percent. In women with baseline proteinuria & secondary hypertension, differentiating superimposed preeclampsia from worsened CH & a great suspicion index is needed. The existence of new-onset thrombocytopenia or an unexpected rise in hepatic enzymes is the common 1st sign of superimposed PE in this category [(6)].

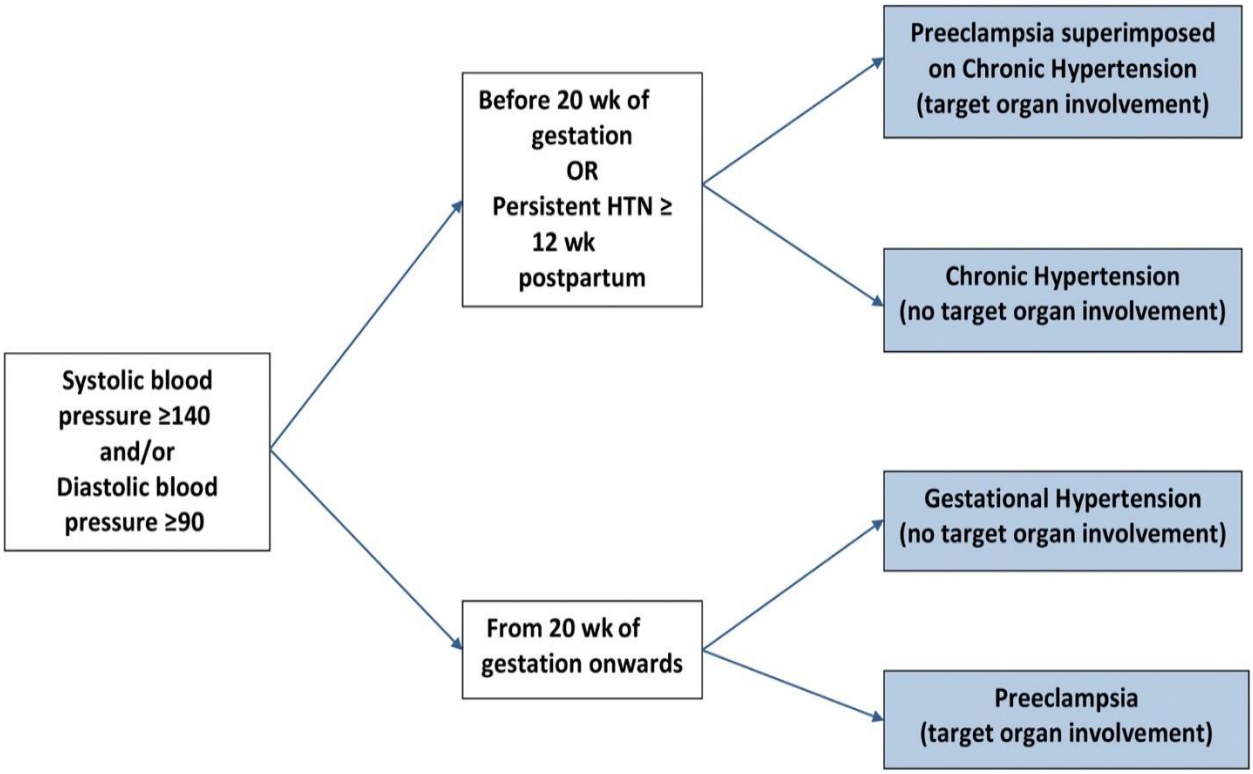

Figure (1): Categorization of hypertensive illnesses in gestation. HTN, hypertension [7].

Physiological changes in blood pressure during pregnancy

Women in a normotensive state entering gestation often exhibit a reduction in BP by the end of the 1st trimester. This reduction is believed to result from the significant vasodilation that appears despite the rise in plasma volume associated with pregnancy. BP typically decreases by five to ten mmHg and maintains this reduced level through gestation until the 3rd trimester, when it ascends to revert to pre-pregnancy values.

In most women with persistent hypertension, BP alterations follow this identical pattern. Consequently, certain hypertensive women achieve normotension during pregnancy, while others who maintain hypertension may have their antihypertensive drugs tapered.

The physiological alterations can confuse the identification of persistent hypertension when a woman presents prenatal care for the 1st time in the 2nd trimester, following the physiological reduction that results in normotension. In such patients, the elevated of prior to pregnancy levels in the 3rd trimester may indicate gestational hypertension. Chronic hypertension may only be accurately diagnosed in retrospect when abnormal blood pressures continue beyond twelve weeks postpartum [8].

Epidemiology

Hypertension is the majority of frequent medical illness appearing during gestation, complicating five to ten percent of all pregnant women. It is additionally the main reason for maternal mortality in industrialized countries, as well as its high occurrence. within 1998 & 2006, the occurrence of hypertension through transfer hospitalizations rose from 67.2 to 81.4 per one thousand deliveries. The rise may partially be due to the rising occurrence of cardiometabolic illnesses in women of childbearing age. Maternal age over forty years, prior to pregnancy overweightness, abnormal weight gain through gestation, in addition to gestational diabetes, are all correlated with heightened possibilities of maternal hypertension [9].

Prevalence in Egypt

The occurrence of PE in Egypt is approximately 6-8% of all pregnant women & can be as great as 15% in referral centers similar to university hospitals [10]. The incidence of eclampsia in Egypt is around 0.3% [11].

Etiology

Conditions that decrease vascular insufficiency & uteroplacental blood flow, involving previously present kidney illness, hypertension, thrombophilia, DM, OSA, & autoimmune disease, are associated with a greater possible hypertensive illness in gestation. Furthermore, women with a prior history of multiple pregnancies, HELLP syndrome, PE, a BMI above thirty, autoimmune diseases, those over thirty-five years of age, the once mothers, or those with a mother's

or sibling history of GH are at a greater possible of evolving GH and an increased possible for progressing to pre-eclampsia [12].

Risk Factors

Risk factors for (GH) involve parity, obesity & a history of previous preeclamptic pregnancies. Several factors involving endothelial dysfunction, placental vascular insufficiency, systemic inflammation, and arterial stiffness have a role in the enhancement of PE [13].

Nonetheless, it remains unclear whether the identical pathophysiological alterations are in addition responsible for gestational hypertension. Moreover, research on the pathways connecting hypertensive illnesses during pregnancy to maternal cardiovascular illness is restricted. A major cohort research revealed a significant correlation among hypertensive disorders of pregnancy & numerous cardiovascular risk factors, involving type II DM, hyperlipidemia, hypertension & elevated BMI [14].

Pathophysiology of hypertension in pregnancy

Any hypertension illness during gestation may lead to preeclampsia. It manifests in up to 35% of women with GH & up to 25% of those with persistent hypertension. The pathophysiology underlying the transition to, or superposition of, pre-eclampsia remains poorly understood. Yet, it is believed to be associated with a process of lower placental perfusion, involving dysfunction of the systemic vascular endothelium. This occurs because of an insufficient cytotrophoblast invasion of the uterine spiral arteries [15].

The placental hypoxia outcome triggers an inflammatory events cascade, affecting the angiogenic factors balance & triggering platelet aggregation, all of which cause the endothelial dysfunction, demonstrated clinically as the pre-eclampsia syndrome. Angiogenic imbalances correlated with pre-eclampsia progression involve reduced levels of angiogenic factors, including VEGF & PIGF, in addition to elevated levels of their antagonist, placental soluble fms-like tyrosine kinase 1 (sFlt-1) [16].

Preventing the linking of PIGF & VEGF with their receptors is a factor in the decrease of NO synthesis, an essential factor in vasodilation & vascular remodeling, in addition to not being able to improve placental ischemia. Early-onset preeclampsia (EOPE), manifesting prior to thirty-four weeks of pregnancy, is believed to be primarily due to syncytiotrophoblast stress resulting in insufficient placentation, while late-onset preeclampsia (LOPE), resulting after thirty-four weeks, is characterized as secondary to the placenta outgrowing its circulation. EOPE is more often correlated with fetal growth restriction than LOPE, which is because of an extended placental dysfunction period [17].

In the postpartum duration, up to 27.5% of women may advance de novo hypertension. This results from several mechanisms, involving the mobilization of fluid from the interstitial to the intravascular space, as well as the vasoactive agents & administration of fluids. The fluid shift enhances cardiac output & stroke volume by up to eighty percent, subsequently a compensatory procedure of vasodilation & diuresis that softens the increase in BP. When examining the present state of adjunct treatments to antihypertensives that have the potential to help prevent preeclampsia, the pathophysiology of HP becomes especially relevant [2].

Diagnosis

HP is identified when (SBP) is ≥ 140 mmHg and/or (DBP) is ≥ ninety mmHg, determined in the office or hospital, confirmation is required, ideally on two separate occasions or at least fifteen minutes apart in cases of severe hypertension (i.e., ≥ 160/110 mmHg as the obstetric literature generally classifies hypertension into mild & severe categories instead of that the 3 grades outlined by European hypertension guidelines) [18].

Table (1): Basic laboratory tests suggested for follow-up cases with hypertension in pregnancy [(1)]

Hemoglobulin & hematocrit	Hemoconcentration supports the identification of GH without or with proteinuria. It signifies severity. Concentrations may be less in very severe patients due to hemolysis
Platelet count	Concentration below 100,000 × 10^9/L may indicate consumption inside the microvasculature. Concentration indicate severity & are predictive of recovery rate in post-partum duration, markedly for women with HELLP syndrome*
Serum ALT, AST	Higher concentration indicates hepatic including. Rising concentration indicates worsening severity
Serum LDH	Higher concentration correlated with hemolysis & liver participation. May reflect severity & may predict potential for post-partum recovery, particularly for women with HELLP syndrome
Proteinuria (twenty-four-hour urine collection)	Standard to quantify proteinuria. If above two grams/day, very close follow-up is necessary. If above three grams/day, delivery should be regarded.
Urinalysis	Dipstick test for proteinuria has significant false (+) & false (-) rates. If dipstick outcomes are + (≥ 1), an additional examination is required, involving albumin/creatinine ratio. the outcomes of the dipsticks are negative; do not rule out proteinuria, particularly a diastolic blood pressure ≥ ninety millimeters of mercury
Albumin to creatinine ratio (ACR)	It can be rapidly assessed with a single spot urine specimen. A result below thirty milligrams/mmol consistently rules out proteinuria. A value of above or equal to thirty milligram/mmol should be considered for a twenty-four-hour urine sample.
Serum uric a`	Higher concentration helps in variance diagnosis of GH & may reflect severity
Serum creatinine	Concentration drops in gestation. Higher concentration recommends rising severity of hypertension; evaluation of twenty-four-hours creatinine clearance may be needed

* High hepatic enzyme levels, *HELLP* hemolysis & reduced platelet count.

Treatment

No pharmacological Treatment of CH

Diet: Decreasing the consumption of salt never improves perinatal or maternal findings, nor affects the possibility of preeclampsia. Nevertheless, preventing excessive salt intake can help regulate BP & reduce the requirement for hypotensive medications [(19)].

Physical Activity: Weight control, normal activities, in addition to decreasing cardiovascular risk factors, like smoking, are crucial suggestions for CH cases. Nonetheless, physical activities require following up by qualified specialists in the corresponding fields. No evidence contraindicates light physical activities in gestation. cases who practice regular physical activity should be motivated to maintain their activity levels, maybe with modifications to the intensity and frequency of their workouts [(20)].

Pharmacological treatment of CH

Antihypertensive medications: In cases with regular BP, hypotensive medications have no evident benefits. It is presently suggested that medical treatment should begin when blood pressure readings reach 140/90 mmHg. According to aims for blood pressure regulation, a controlled clinical experiment has tested 2 separate control regimes: (1) Tight (DBP up to eighty-five mmHg) & (2) Less-tight (DBP one hundred mmHg) and failed to find significant variances regarding perinatal results or superimposed PE among categories. Nonetheless, cases in the tight category have reduced the possibility of severe hypertension during pregnancy. Table (2) illustrates the medications that are most frequently utilized in clinical practice [(21)].

Table (2): Highest frequency antihypertensive medications for use in gestation. From: Chronic hypertension in pregnancy [19]

Drug	Action	Dosage
Methyldopa	Centrally acting Alph-two adrenergic agonists	250–2000 milligram/day orally in 3 to 4 separated doses Frequently initiated at 250 milligrams, 3 doses, daily
Prazosin	Alpha-one peripheral blockers	Initial dose of 1.0 milligram, one time a day, for seven days Increments of 1.0 milligram/day each week until desired control Maximum twenty milligram/day
Labetalol	Beta blockers	200–2400 milligram/day orally in 2 to 3 separated doses Frequently initiated at one to two hundred milligrams, 2 times daily
Nifedipine	Calcium channel blocker	Ten to twenty milligrams orally in 2 to 3 doses. Maximum one hundred eighty milligram/day Extended-release twenty to sixty milligrams once daily. Maximum one hundred twenty milligrams/day
Hydrochlorothiazide	Diuretic	12.5–50.0 milligrams/daily, one dose

The central adrenergic inhibitor methyldopa has a significant amount of clinical experience in the field of obstetrics. It has been reported that there are no bad effects or significant fetal abnormalities, and this medication is the 1st choice in numerous countries throughout the world. α-Methylnorepinephrine is formed from the metabolism of Methyldopa and substitutes for norepinephrine in the neurosecretory vesicles of terminal adrenergic neurons. Systematically, degradation by monoamine oxidase does not easily affect it, causing a decrease in systemic vascular resistance & sympathetic tone, correlated with a low reduction in heart rate. The BP regulation is regular, with effect in around six to eight hours, owing to its indirect mechanism of action. Some negative impacts include decreased alertness, tiredness or depression, impaired sleep & decreased salivation. Approximately five percent of cases may exhibit elevated hepatic enzymes, potentially leading to an interpretation of liver impairment because of pulmonary embolism [21].

Thiazide diuretics are presently regarded as safe medications for cases with chronic hypertension, except during lactation duration. It is a frequent alternative in the clinical practice of cardiologists & clinicians. Consequently, for cases now using these medications who get pregnant, there are no justifications for discontinuation. Nevertheless, facing insufficient placental function with a decrease in the superimposed pre-eclampsia or amniotic fluid volume, diuretics should be interrupted. In emergency cases, like cardiac arrest, acute pulmonary edema, or kidney dysfunction, furosemide is the preferred [21]. Amlodipine, either alone or in conjunction with other hypotensive agents, is another choice within this category of safe hypotensive medications [22].

Doppler ultrasonography

Doppler ultrasonography is a crucial diagnostic instrument for identifying and controlling a range of medical conditions. The utilization of Doppler ultrasonography by healthcare professionals has grown more prevalent due to advancements in technology and increased cost-effectiveness. Furthermore, there was an enhanced utilization of point-of-care ultrasonography as a diagnostic modality. Total of clinicians require knowing the potential pitfalls, fundamental principles, as well as the potential benefits of Doppler ultrasonography [23].

The application of clinical ultrasonography maintained to develop over the past fifty years. The imaging modality known as ultrasonography has many advantages, including the ability to deliver real-time imaging on a cheap budget and without the use of any potentially dangerous ionizing radiation. Its benefit has been enhanced as a result of the addition of Doppler. It is often used to evaluate organ perfusion & vascular patency, in addition to enhanced echocardiography to measure valvopathy & heart function. To enhance imaging and make accurate clinical decisions, users need to realize the principles of various Doppler methods & the processing of Doppler data [24].

Doppler ultrasound is a method that is both non-invasive & safe, and it is used to evaluate the maternal & fetal circulation patterns of both the mother & the fetus during gestation. The use of Doppler ultrasound in preeclamptic hypertension (PIH), more specifically in the identification of pre-eclampsia and the negative results that occur from it, has been recommended by different scientific researches. Doppler velocimetry assesses abnormal fetal hemodynamics caused by alterations in placental resistance. Doppler indices can assist in identifying fetuses with enhanced placental resistance & reduced cerebral resistance. In an obstetric case group characterized by a significant occurrence of complications like PIH, Doppler indices from fetal circulation may accurately predict negative perinatal results [(25)].

Maternal and fetal results in pregnant women with hypertensive disorders

Globally, HDP remains the primary due to perinatal & maternal mortality & morbidity, with a measured number of 500,000 perinatal deaths & 30,000 maternal deaths/year. HDP is correlated with bad perinatal results such as prematurity, intrauterine growth restriction, perinatal asphyxia, neonatal mortality, preterm delivery & stillbirths. HDP outcome in an enhanced possibility of bad maternal results involving placental abruption, stroke, HELLP syndrome, kidney damage, pulmonary edema and hepatic injury, in addition to death [(26)].

HELLP is a syndrome described as hemolysis, high hepatic enzymes & decreased platelets. HELLP syndrome manifests in approximately 0.5 to 0.9% of all pregnant women and complicates from 10-20% of cases of severe PE. HELLP syndrome is a frequent determinant of fetal & maternal mortality in women with HDP [(27)].

Most feto-maternal complications of HDP appear in countries with middle or low incomes caused by inadequate healthcare services and insufficient maternal and neonatal care. The WHO estimates that the frequency of PE is sevenfold greater in countries with middle or low incomes than in countries with high incomes, and the mortality possible for pregnant women due to PE/eclampsia in countries with low incomes is three hundred times greater than in countries with high incomes [(28)].

Results from high BP for the mother & infant can involve the following [(29)] :

- **For the mother:** Stroke, eclampsia, preeclampsia, the requirement for labor stimulation (Administering medication to initiate labor), as well as placental abruption (The placenta dividing from the uterine wall).
- **For the baby:** pre-term delivery (Birth that occurs previously thirty-seven weeks of pregnancy) as well as low birth weight (When a baby is born weighing less than eight ounces, 5 pounds). When the mother's BP increases, it is difficult for the newborn to get enough O_2 & nutrients to grow, so this leads to premature birth.

In addition to pregnancy complications, elevated BP and hypertension are well-known to be correlated with a great possibility of cardiovascular illness, involving fatal conditions like myocardial infarction, cardiac failure, stroke, and abdominal aortic aneurysm. Aiming to decrease the probability of cardiovascular illness, the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines have studied the suggestions for hypertension identification, characterizing classifying stage I hypertension as DBP measurement among 80 & 89 mmHg or SBP measurement among 130 & 139 mmHg, depending on compelling indication from cardiovascular researches [(30)] .

CONCLUSION

Doppler ultrasound is useful in predicting maternal complications like progression to severe preeclampsia or HELLP syndrome. Its role is particularly significant in resource-limited settings where access to more advanced fetal monitoring techniques may be unavailable. Overall, the integration of Doppler researches into the routine care of hypertensive pregnancies increases the possibility of improving maternal stratification & fetal prognosis by allowing for better clinical decision-making.

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