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The Significance of Hemodynamic Markers for the Early Detection of Preeclampsia in Pregnant Women with Chronic Arterial Hypertension

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Abstract Chronic arterial hypertension (CAH) is a significant risk factor for obstetric complications, including the development of preeclampsia, which markedly increases maternal and perinatal morbidity and mortality rates. Hemodynamic markers play a crucial role in the early diagnosis of this condition, allowing for the assessment of intracardiac and central hemodynamics, detection of left ventricular diastolic dysfunction, and evaluation of volumetric disturbances. The analysis of these parameters contributes to the timely prediction of complications and facilitates the development of individualized management strategies for high-risk pregnant women.

Keywords Chronic arterial hypertension, Preeclampsia, Pregnancy, Hemodynamic markers, Early diagnosis, Cardiovascular complications, Maternal mortality, Perinatal outcomes

1. Introduction

Arterial hypertension (AH) is among the most prevalent diseases both in the general population and among women of reproductive age. The steady increase in its prevalence and associated cardiovascular complications necessitates the search for new approaches to diagnosis and treatment. In recent years, researchers have shown increasing interest in predicting and diagnosing the early stages of hypertensive syndromes, owing to their significant impact on maternal and perinatal mortality [1,3].

Chronic arterial hypertension (CAH) remains one of the leading causes of severe cardiovascular complications and mortality worldwide, including among women of reproductive age. According to the World Health Organization (WHO), CAH causes approximately 10 million deaths annually, with an additional 6.3 million individuals becoming disabled. The overall number of patients exceeds 1 billion globally. The relevance of this issue to obstetrics lies in the fact that CAH is an important predictor of future cardiovascular pathology and ranks second among the causes of maternal mortality [4,8].

Hypertensive disorders complicate up to 10% of pregnancies, of which approximately one-third are associated with CAH, while the remaining cases are linked to gestational hypertension. The presence of CAH significantly increases the risk of superimposed preeclampsia, which worsens the course of pregnancy in 25–70% of cases, increasing the frequency of obstetric and perinatal complications. Pregnancy against the background of arterial hypertension is accompanied by profound changes in the cardiovascular system. When preeclampsia develops on top of CAH, it exacerbates left ventricular diastolic dysfunction, disrupts intracardiac and central hemodynamics, contributes to the development of asymptomatic heart failure, and negatively affects fetal intrauterine growth. In this regard, the assessment of hemodynamic markers that reflect cardiac output, minute performance, and volumetric changes in the maternal body is of particular importance [2,6].

At present, the relationship between hemodynamic disturbances and endothelial dysfunction, as well as their role in the pathogenesis of preeclampsia in women with CAH, remains insufficiently clarified. The study of these markers allows for the prediction of maternal and fetal risks and supports the development of individualized approaches to the management of high-risk pregnancies [5,7].

Aim of the Study: To determine the role of hemodynamic markers in the early diagnosis of preeclampsia developing against the background of chronic arterial hypertension.

2. Materials and Methods

A screening examination was conducted on 150 pregnant women, divided into three groups:

- Group I — pregnant women with chronic arterial hypertension complicated by preeclampsia (n = 50);

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- Group II — pregnant women with a physiological course of pregnancy who subsequently developed preeclampsia (n = 50);
- Group III — pregnant women with an uncomplicated physiological pregnancy (n = 50).

The following parameters were evaluated in all patients:

- indicators of systemic hemodynamics (blood pressure, systolic arterial pressure, total peripheral vascular resistance);
- central and regional hemodynamics (renal and uteroplacental-fetal blood flow) assessed by Doppler ultrasound;
- clinical and biochemical parameters (urea, creatinine, total protein, etc.);
- blood coagulation indicators (platelets, prothrombin index, activated partial thromboplastin time, clotting time, INR, fibrinogen);
- Doppler measurements of uteroplacental and renal blood flow.

Statistical analysis of the data was performed using Student's t-test. Normality of distribution was assessed using the kurtosis test, while equality of variances was checked using Fisher's F-test. Differences were considered statistically significant at $p < 0.05$.

3. Results

Status of homeostatic parameters in women with superimposed preeclampsia. This group included 50 pregnant women with chronic arterial hypertension and proteinuria, in whom superimposed preeclampsia was diagnosed at 20–22 weeks of gestation. The mean age of patients was 36.1 ± 2.4 years. By parity: primiparous — 16 (32%), multiparous — 34 (68%). The diagnosis of superimposed preeclampsia was established when the following criteria were met:

- newly detected proteinuria (≥ 0.3 g/day) after 20 weeks of pregnancy, or worsening of pre-existing proteinuria;
- progression of arterial hypertension in women whose blood pressure was well controlled before 20 weeks of pregnancy;
- onset of multi-organ dysfunction symptoms after 20 weeks of gestation.

Table 1. Comparative analysis of clinical and biochemical parameters of blood and urine in pregnant women of the studied groups during the second trimester (n=100)

Indicators	Group 1, control, n=50	Group 2, moderate PE, n=50	Group 3, superimposed, n=30	P_{2-1}	P_{3-1}
Hb, g/L	10,4 ±0,21	7,8 ±0,26	7,4 ±0,32	<0,001	<0,001
Erythrocytes, 10 ¹²/L	3,0 ±0,08	2,7 ±0,04	2,4 ±0,05	<0,001	<0,001
Ht, %	35,2 ±0,33	27,6 ±0,48	27, ±0,45	<0,001	<0,001
Total protein, g/L	62,5 ±0,35	56,5 ±1,41	56,3 ±0,93	<0,001	<0,001
Urea, mmol/L	4,2 ±0,03	6,4 ±0,24	6,8 ±0,22	<0,001	<0,001
Serum creatinine, mkmol/L	68,9 ±0,90	74,5±2,41	75,3 ±2,29	<0,05	<0,01
Serum uric acid, mkmol/L	178,4 ±5,4	285,2 ±4,3	299,3 ±2,7	<0,05	<0,01
Daily diuriesis, mL	1130 ±211	975 ±19,40	956,3±20,8	<0,001	<0,001
Microalbuminuria (MUA), mkg/mg	28,5 ±0,76	38,5 ±1,73	46,4 ±1,49**	<0,001	<0,001

Note: Statistical significance is presented relative to Groups II and III.

Table 2. Comparative Indicators of Central Hemodynamics in Pregnant Women with Superimposed Preeclampsia (28–32 weeks of gestation, n=100).

Indicators	Group 2, moderate PE, n=50	Group 3, superimposed PE, n=30	P
Stroke volume (SV), mL	73,6 ±1,24	71,3 ±0,69	>0,05
Stroke index (SI), ml/m ²	40,5 ±0,76	39,2 ±0,39	>0,05
Heart rate, bpm	90,0 ±1,67	97,2 ±0,93	<0,05
Cardiac output (CO), L/min	6,8 ±0,13	6,9 ±0,08	>0,05
Cardiac index (CI), L/min/m ²	3,6 ±0,06	3,8 ±0,04	>0,05
Diastolic BP (DBP), mm.Hg	94,3 ±1,73	102,3 ±1,72	<0,05
Total peripheral vascular resistance (TPVR), dyn·s·cm^{-5}	1498 ±28,2	1532 ±32,3	>0,05
End-systolic volume (ESV), mL	37,6 ±0,65	35,2 ±0,74	<0,05
End-diastolic volume (EDV), mL	101,4 ±1,79	99,1 ±2,14	>0,05
Ejection fraction, %	70,4 ±1,24	71,2 ±0,81	>0,05

Table 3. Comparative Indicators of Uteroplacental and Fetal Blood Flow in Women with Superimposed Preeclampsia (28–32 weeks of gestation, n=100)

Regional blood flow.	Indicators	Group 2, moderate PE, n=50	Group 3, superimposed PE, n=50	P
Uterine artery	S/D ratio	2,67 ±0,06	2,71 ±0,04	>0,05
	RI	0,57 ±0,01	0,65 ±0,02	<0,001
Umbilical artery	S/D ratio	2,48 ±0,05	2,52 ±0,02	>0,05
	RI	0,63 ±0,01	0,68 ±0,02	<0,05
Fetal middle cerebral artery	S/D ratio	2,40 ±0,05	2,44 ±0,03	>0,05
	RI	0,45 ±0,01	0,50 ±0,02	<0,05

As control groups, 50 pregnant women with moderate preeclampsia and 50 women with physiological pregnancies were selected. All patients, upon manifestation of clinical signs of preeclampsia, were hospitalized in a specialized maternity facility, where dynamic monitoring of maternal and fetal status was conducted starting from the second trimester.

On comparison of laboratory data, it was found that both study groups demonstrated elevated urea and creatinine levels above the normal range; however, no statistically significant relationship with the form of preeclampsia was identified. Serum and urinary uric acid concentrations were similarly high. In women with chronic arterial hypertension (CAH) and superimposed preeclampsia, a significant tendency toward increased microalbuminuria (MAU) was recorded.

In patients with superimposed preeclampsia, a decrease in stroke volume was observed, while cardiac output was maintained through compensatory increases in heart rate. Diastolic blood pressure and total peripheral vascular resistance were elevated, though the changes were not statistically significant. A significant reduction in end-systolic volume was noted, while end-diastolic volume showed only a tendency toward decrease. Ejection fraction remained within normal limits.

It is evident that maternal hemodynamic alterations negatively affect fetal circulation. This is demonstrated by abnormalities of blood flow in the fetal middle cerebral artery recorded by the systolic/diastolic (S/D) ratio and resistance index (RI), as well as by fetal growth and developmental retardation. Analysis of baseline Doppler tracings revealed common patterns of change in the velocity waveforms of the umbilical arteries with advancing gestational age due to the diastolic component. We registered episodic cycles of reduction of end-diastolic velocity to critically low values, often associated with fetal breathing movements. Given the straightforward interpretation of quantitative fetoplacental blood-flow parameters, Doppler velocimetry can be regarded as an early and objective method for assessing the fetoplacental system. Fetal growth impairment in the setting of arterial hypertension is directly related to disturbances in maternal hemodynamics and gas exchange, since hypertensive disease leads to substantial changes in peripheral and organ circulation, including the uterine arterial bed. Fetal growth restriction (FGR) was diagnosed in 52.3% of cases among pregnant women with superimposed preeclampsia. The diagnosis was established on the basis of placentome try and photometry during ultrasound examination. It is obvious that adverse intrauterine conditions largely determine the postnatal course; therefore, meticulous dynamic monitoring of these pregnancies and timely selection of the method and timing of delivery are of prime importance. Independent predictors of superimposed preeclampsia included hyperuricemia and microalbuminuria (MAU), detected both in patients with isolated preeclampsia and in pregnant women with combined pathology during the second trimester. In the combined form of preeclampsia, disturbances of regional hemodynamics (increased vascular resistance indices in uterine and fetal arteries) were more pronounced and correlated with various patterns of the mother's central hemodynamics. The dynamics of arterial blood pressure in pregnant women with preeclampsia in our cohort corroborate published data indicating a more aggressive disease course in the combined (superimposed) variant, which is particularly characteristic for women with hypertension predating pregnancy and frequently remaining undiagnosed. For the majority of patients in our study, this factor determined the early manifestation of clinical features of preeclampsia. Analysis of the prognostic significance of metabolic markers demonstrated that elevated serum uric acid and microalbuminuria, beginning from the second trimester, were significantly more common in patients who developed superimposed preeclampsia. Therefore, these parameters should be considered early and independent predictors of preeclampsia in women with chronic arterial hypertension. Based on the conducted investigations, we determined that pregnant women with arterial hypertension complicated by preeclampsia exhibit a characteristic pattern of hemodynamic changes reflecting the severity of the pathological process. The obtained data support the hypothesis of staged hemodynamic disruption and justify the concept of individualized antihypertensive therapy tailored to the identified central hemodynamic type. Management strategies for pregnancy and delivery in patients with preeclampsia should be based on identification of the pathogenetic variant of disturbances across central, systemic, maternal and regional (uteroplacental and fetal) hemodynamics, the degree of their expression, and the clinical severity of the disease. Hemodynamic markers provide valuable information for the early detection and risk stratification of preeclampsia in pregnant women with chronic arterial hypertension.

Monitoring of central and regional hemodynamic parameters together with metabolic markers such as serum uric acid and microalbuminuria enables earlier identification of patients at highest risk, informs individualized management decisions, and may improve maternal and perinatal outcomes.

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