ORIGINAL RESEARCH

Assessing Left Ventricular Systolic Function in Patients with Pregnancy-Induced Hypertension Using Three-Dimensional Speckle Tracking Technology

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ABSTRACT

Objective • This study investigates the clinical utility of three-dimensional speckle tracking technology in assessing left ventricular systolic function in pregnancy-induced hypertension syndrome (PIH).

Methods • We retrospectively enrolled 70 patients with diagnosed PIH treated at our institution between July 2019 and August 2021 as the study group. A total of 70 healthy pregnant women undergoing routine antenatal examinations at the same institution during the same period were included in the control group. Two-dimensional conventional echocardiography measured left ventricular parameters in both groups. Three-dimensional speckle tracking technology analyzed Left Ventricular Global Longitudinal Peak Strain (LVGLS), Left Ventricular Global Radial Peak Strain (LVGRS), and Left Ventricular Global Circumferential Peak Strain (LVGCS). Differences in left ventricular systolic function and pregnancy outcomes were compared.

Results • In the study group, LVEDD, LVPWTd, and IVSTd (47.67±4.88, 10.68±1.21, 11.24±1.03) exceeded those in the control group (45.21±5.65, 8.17±0.98, 8.91±0.37). LVEF (62.12±5.63) was lower than the control group (65.25±5.17) (all $P < .05$). LVGLS, LVGCS, and LVGAS in the study group (-15.66±1.07, -20.17±2.89, -23.17±3.43) were higher than the control group (-20.14±1.27, -25.17±1.36, -37.68±3.29), while LVGRS (30.29±3.61) was lower than the control group (34.18±4.08) (all $P < .05$). The study group had 72.86% natural deliveries and 27.14% cesarean sections; the control group had 31.43% natural deliveries and 68.57% cesarean sections (all $P < .05$). Weeks of delivery and birth weight in the study group (36.87±1.23, 2.71±0.41) were lower than the control group (38.96±1.54, 3.41±0.78) (both $P < .05$).

Conclusions • Compared to traditional methods, three-dimensional speckle tracking technology more sensitively detects left ventricular strain and rotation in PIH patients. It holds clinical relevance in early left ventricular dysfunction detection, effectively mitigating adverse pregnancy outcomes and warranting clinical adoption and application. (*Altern Ther Health Med.* 2024;30(4):185-189)

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INTRODUCTION

Pregnancy-induced hypertension (PIH)[1] encompasses a range of conditions characterized by the simultaneous presence of pregnancy and hypertension. These conditions include gestational hypertension, pre-eclampsia, eclampsia, early-stage complications of chronic hypertension with eclampsia, and chronic hypertension. PIH represents a distinct obstetric complication that affects pregnant women, posing a significant threat to maternal and fetal health and life safety.[2]

The pathogenesis of PIH is multifaceted and may involve genetic factors and nutritional deficiencies. This condition typically presents with a range of clinical manifestations, including elevated blood pressure, proteinuria (which can result in foamy urine), edema, and potential damage to multiple organs in the body. In severe cases, convulsions (eclampsia) and coma may also occur. Currently, drug therapy represents the primary clinical approach, with the termination of pregnancy considered if necessary.[4,5]

According to recent statistics, the PIH incidence rate in China is around 9.4%, while globally, it ranges from 7% to 12%.[6] PIH presents severe risks to maternal cardiac health and increases the likelihood of placental circulation disorders. As PIH progresses, symptoms of ischemia and hypoxia may emerge, aggravating fetal intrauterine hypoxia. This, in turn, can adversely impact fetal cardiac development, resulting in abnormal fetal cardiac function and further hindering fetal growth and development, ultimately leading to growth restriction.

Speckle tracking technology is a method capable of identifying myocardial acoustic speckles, tracking the movement trajectory of the myocardium, and subsequently measuring the displacement of myocardial tissue. This technique offers a simple, non-invasive, and reliable approach to studying cardiac muscle movement trajectories. It has found widespread application in clinical practice and received high approval. 3D Speckle Tracking Imaging (3D-STI)[7] represents a high-resolution, highly sensitive ultrasound detection technology. It involves tracking myocardial speckles in two-dimensional space by analyzing dynamic three-dimensional images of the heart.

The motion trajectory is utilized to calculate the deformation parameters of myocardial motion.[8] This approach offers a reliable and feasible means to introduce new deformation parameters. Unlike tissue Doppler, it is not limited by angle dependence, and unlike traditional two-dimensional speckle tracking technology, it operates in three-dimensional space.[9] Therefore, it provides more precise evaluations of local and overall myocardial function. This testing method is characterized by high repeatability and accuracy and is not influenced by human factors. It enables real-time and accurate assessments of a patient's left ventricular function and myocardial changes.[10,11]

This study aimed to investigate the clinical utility of 3D-STI in assessing left ventricular systolic function among patients with PIH to advance our understanding and improve maternal and fetal health outcomes.

MATERIALS AND METHODS

Study Design

We conducted a retrospective analysis that involved two groups of participants. The first group consisted of 70 patients who had previously been diagnosed with PIH and received treatment at our hospital between July 2019 and August 2021. The second group comprised 70 healthy pregnant women who underwent routine antenatal examinations at the same hospital during the same period and served as our control group.

Patients Selection

The research group included pregnant women aged between 21 and 39 years, with an average age of 25.63±3.98 years. Their gestational age ranged from 29 to 33 weeks, with an average of 29.83±2.02 weeks. The control group comprised pregnant women aged between 22 and 38 years, with an average age of 26.01±3.65 years, and their gestational age ranged from 28 to 32 weeks, with an average of 29.12±2.36 weeks. Importantly, there were no significant differences in the general demographic data between these two groups of patients, ensuring their comparability. Detailed demographic information is presented in Table 1.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: (1) All participants met the clinical diagnostic criteria for gestational hypertension or mild preeclampsia outlined in the 8th edition of *Obstetrics and Gynecology*[12]; (2) The initial diagnosis of hypertension occurred between the 20th and 24th gestational week, and all participants were carrying singleton pregnancies; (3) Participants exhibited no signs of cephalopelvic disproportion, abnormalities in the birth canal, or uterine contractions; (4) Comprehensive prenatal care records were available for review.

Exclusion criteria were as follows: (1) Participants with pre-existing medical conditions such as hypertension and cardiovascular disease before pregnancy were excluded; (2) Individuals with other pregnancy-related conditions were also excluded; (3) Participants with mental illnesses were not included in the study; (4) Those with abnormal coagulation function were excluded; (5) Individuals with severe gynecological diseases were excluded from the study.

Imaging and Data Collection

Data and images were gathered from the research and control groups of pregnant women through the following procedures.

Patient Positioning and Electrocardiogram Monitoring. All subjects were positioned either in the left lateral or supine position, with synchronized electrocardiogram monitoring.

Two-Dimensional Echocardiography. Initially, two-dimensional echocardiography was employed for routine examination, including measurements of parameters such as left ventricular end-diastolic diameter (LVEDD), left ventricular ejection fraction (LVEF), interventricular septum thickness at end-diastole (IVSTd), and left ventricular posterior wall thickness at end-diastole (LVPWTd) in the M-mode, utilizing the parasternal long-axis view of the left ventricle. Additionally, the relative wall thickness (RWT) was calculated.

Color Doppler Ultrasound. A color Doppler ultrasound diagnostic instrument equipped with a PST-30SBT two-dimensional probe and PST-25SX three-dimensional matrix probe, along with three-dimensional quantitative analysis software, was utilized. The image quality was adjusted to ensure clear visualization of the endocardial border. Once the image stability and quality met the requirements, participants were instructed to hold their breath, and the "Full Volume" mode was activated to measure parameters such as global longitudinal strain (GLS), global circumferential systolic strain (GCS), global radial systolic strain (GRS), and global area strain (GAS) of the left ventricle.[13,14] Subsequent follow-up assessments were conducted to observe pregnancy outcomes and neonatal conditions.

Evaluation Criteria

In this study, the evaluation criteria encompassed the following components.

Two-Dimensional Echocardiography Assessment. Routine two-dimensional echocardiography was employed to conduct a thorough examination of pregnant women. Parameter values such as LVEDD, LVEF, IVSTd, and LVPWTd were carefully measured, recorded, and subjected to comparative analysis.

Three-Dimensional Speckle Tracking Imaging (3D-STI) Assessment. Utilizing 3D-STI technology, we measured and compared parameter values, including left ventricular global longitudinal strain (LVGLS), left ventricular global radial systolic strain (LVGRS), left ventricular global circumferential systolic strain (LVGCS), and left ventricular global area strain (LVGAS).

Pregnancy Outcome and Neonatal Condition Observation. A comprehensive follow-up was conducted to closely monitor pregnancy outcomes and neonatal conditions within the research and control groups. The observations included assessing the weeks of delivery, the mode of delivery, and the birth weight of newborns.

Statistical Analysis

The data was processed using SPSS 22.0 software (IBM, Armonk, NY, USA). Enumeration data were presented as counts and percentages [n (%)], while measurement data were expressed as means with standard deviations ($\bar{x} \pm s$). Chi-square tests (χ^2) were applied for enumeration data, and *t* tests were employed for measurement data. A significance level of $P < .05$ was considered statistically significant.

RESULTS

Conventional Ultrasound of the Left Ventricle

The results of a conventional ultrasound examination of the left ventricle revealed significant differences between the study and control groups. In the study group, the parameters of LVEDD, LVPWTd, and IVSTd were found to be higher, with values of 47.67±4.88, 10.68±1.21, and 11.24±1.03, respectively, compared to the control group with values of 45.21±5.65, 8.17±0.98, and 8.91±0.37 (all $P < .05$). Furthermore, the LVEF parameters were lower in the study group (62.12±5.63) compared to the control group (65.25±5.17) (all $P < .05$). For detailed information, refer to Table 2.

Three-Dimensional Strain Parameters

The assessment of three-dimensional strain parameters revealed notable differences between the study group and the control group. In the study group, the LVGLS, LVGCS, and LVGAS parameter values were -15.66±1.07, -20.17±2.89, and -23.17±3.43, respectively. These values were higher than those observed in the control group, which recorded values of -20.14±1.27, -25.17±1.36, and -37.68±3.29, respectively (all $P < .05$). Conversely, the LVGRS parameter was notably lower in the study group (30.29±3.61) compared to the control group (34.18±4.08) (all $P < .05$). For detailed information, refer to Table 3.

Table 1. Patient Demographics ($\bar{x} \pm s$)

Groups	Study Group	Control Group	*t*	*P* value
n	70	70	-	-
Age	21-39	22-38	-	-
Mean Age	25.63±3.98	26.01±3.65	0.589	.557
Gestational Age	29-33	28-32	-	-
Mean Gestational Weeks	29.83±2.02	29.12±2.36	1.192	.058
Parity	1-4	1-4	-	-
Mean Parity	2.21±0.42	2.25±0.43	0.557	.578
Gravida	1-3	1-3	-	-
Mean Gravida	1.91±0.54	1.92±0.53	0.111	.912

Table 2. Comparison of Conventional Ultrasonography Measurements of the Left Ventricle in Two Groups of Pregnant Women ($\bar{x} \pm s$)

Groups	n	LVEDD (mm)	LVPWTd (mm)	IVSTd (mm)	LVEF (%)
Study Group	70	47.67±4.88	10.68±1.21	11.24±1.03	62.12±5.63
Control Group	70	45.21±5.65	8.17±0.98	8.91±0.37	65.25±5.17
t	-	2.757	13.487	17.812	3.426
P value	-	.007	<.001	<.001	.001

Note: This table presents a comparison of various parameters related to conventional ultrasonography of the left ventricle between the study group (patients with pregnancy-induced hypertension) and the control group (healthy pregnant women).

Abbreviations: LVEDD, left ventricular end-diastolic diameter; LVPWTd, left ventricular posterior wall thickness at end-diastole; IVSTd, interventricular septal thickness at end-diastole; and LVEF, left ventricular ejection fraction.

Table 3. Comparison of Three-Dimensional Strain Parameters in Pregnant Women from Two Groups ($\bar{x} \pm s$)

Groups	n	LVGLS	LVGCS	LVGRS	LVGAS
Study Group	70	-15.66±1.07	-20.17±2.89	30.29±3.61	-23.17±3.43
Control Group	70	-20.14±1.27	-25.17±1.36	34.18±4.08	-37.68±3.29
t	-	22.571	13.097	5.974	25.543
P value	-	<.001	<.001	<.001	<.001

Abbreviations: LVGLS, Left Ventricular Global Longitudinal Strain; LVGCS, Left Ventricular Global Circumferential Strain; LVGRS, Left Ventricular Global Radial Strain; LVGAS, Left Ventricular Global Area Strain.

Table 4. Comparison of Delivery Methods in Two Groups of Pregnant Women (%)

Groups	n	Natural Delivery	Cesarean Section
Study Group	70	51(72.86)	19(27.14)
Control Group	70	22(31.43)	48(68.57)
χ^2	-	24.073	
P value	-	<.001	

Note: The table displays the number of cases for each delivery method, with percentages in parentheses.

Table 5. Comparison of Newborns in Two Groups ($\bar{x} \pm s$)

Groups	n	Delivery Weeks (weeks)	Newborn Birth Weight (kg)
Study Group	70	36.87±1.23	2.71±0.41
Control Group	70	38.96±1.54	3.41±0.78
t	-	8.872	6.646
P value	-	<.001	<.001

Note: The values are presented as means with their respective standard deviations.

Pregnancy Outcomes

Mode of Delivery. Regarding the mode of delivery, the study group exhibited a distribution of 51 cases (72.86%) of natural delivery and 19 cases (27.14%) of cesarean section. In contrast, the control group displayed 22 cases (31.43%) of natural birth and 48 cases (68.57%) of cesarean section. These differences were statistically significant (all $P < .05$). Refer to Table 4 for details.

Neonatal Outcomes. In terms of neonatal outcomes, our findings indicated significant variations between the study group and the control group. The study group had a mean delivery gestational age of 36.87±1.23 weeks and an average birth weight of 2.71±0.41 kilograms. In comparison, the control group had a higher mean delivery gestational age of 38.96±1.54 weeks and a greater average birth weight of 3.41±0.78 kilograms. These differences were statistically significant (both $P < .05$). Detailed results are presented in Table 5.

DISCUSSION

PIH is a significant and severe obstetric complication[15] commonly encountered during pregnancy. Despite extensive research, the precise pathogenesis of this condition remains elusive.[16] Epidemiological studies have revealed that the incidence of pregnancy-induced hypertension syndrome falls within a range of 5% to 12%. With the implementation of the two-child policy in our country's family planning program, there has been a notable rise in consultations with older pregnant women and women undergoing the lying-in period. This demographic shift has led to a steady increase in the clinical diagnosis of pregnancy-induced hypertension syndrome over the years.[17]

In recent years, with the continuous advancement of two-dimensional and three-dimensional ultrasonic strain technology in clinical applications, the assessment of myocardial function in various cardiac diseases has progressively gained precision. A noteworthy addition to this technology is 3D-STI, which provides a novel means of measuring and evaluating myocardial function, encompassing three-dimensional assessments of longitudinal, radial, and circumferential strains.

Tracking individual speckle units not only provides information on speckle movement displacement but also allows us to obtain a three-dimensional representation of the myocardium. It suggests that assessing strain energy in a single direction enables a more precise evaluation of cardiac myocardial motor function.[14,18] This approach offers a comprehensive and detailed assessment of myocardial function in a shorter amount of time.

In recent years, several scholars have studied the left ventricular function of patients with pregnancy-induced hypertension using 3D-STI.[19] However, Chinese studies are scarce on this subject. The findings of our study revealed that within the study group, the parameters of LVEDD, LVPWTd, and IVSTd were notably higher compared to those in the control group. Additionally, the LVEF parameters were found to be lower in the study group compared to the control group.

Relevant research findings indicate that achieving systolic function in the left ventricular myocardium involves the coordinated interaction of its three layers. The left ventricular wall is comprised of myocardial fibers oriented in distinct directions. The innermost layer consists of circular muscle fibers, while the outer layer consists of oblique muscle fibers. The initial deformation of the subendocardial myocardium is primarily triggered by elevated blood pressure, resulting in increased ventricular wall stress and subsequent microvascular dysfunction, along with myocardial fibrosis and other associated changes.

In patients with PIH, the initial manifestation of left ventricular systolic dysfunction is characterized by impaired longitudinal myocardial contraction, which serves as a crucial parameter for early clinical detection of left ventricular systolic dysfunction. Additionally, GAS represents the alteration in ventricular wall area during systole. Compared to the end-diastolic wall area ratio, GAS provides more precise parameters for quantifying global and regional myocardial function.[18-19]

In patients with PIH, we observed a decrease in subendocardial myocardial perfusion and myocardial contractility, combined with increased cardiac preload in both groups. These factors collectively weakened the reversal motion of subepicardial myocardial fibers, leading to excessive ventricular rotation. From the results of this study, we found that two-dimensional conventional echocardiography in both groups of pregnant women measured parameters such as left ventricular inner diameter, ventricular wall thickness, and left ventricular ejection fraction. While there are slight variations in blood parameters, these differences remain within the normal range.

The results obtained through 3D-STI demonstrate a notable and varying reduction in left ventricular systolic function among patients with PIH. The impairment of myocardial motion predominantly begins in the long-axis direction. This finding implies that, even when LVEF remains within the normal range, the myocardial mobility of pregnant women with significantly elevated blood pressure may already be compromised. These findings emphasize the speed and sensitivity of 3D-STI in detecting myocardial damage and functional alterations in the left ventricle. These findings align with a previous study conducted by Maurizio et al.[20]

The observed differences highlight the remarkable ability of 3D-STI to detect subtle myocardial dysfunction in patients with PIH, even when conventional indicators such as LVEF fall within normal limits. These findings emphasize the importance of conducting comprehensive cardiac assessments in cases of PIH, revealing subclinical cardiac alterations that might remain unnoticed when relying solely on standard parameters. These differences are clinically significant as they have the potential to improve the management and outcomes of patients with PIH. They allow for timely interventions and careful cardiac monitoring, reducing the risk of cardiovascular complications during pregnancy.

Additionally, during the later stages of this study, it was observed that within the research group, there were 51 cases

(72.86%) of natural deliveries and 19 cases (27.14%) of cesarean sections. In contrast, the control group experienced 22 cases (31.43%) of natural births and 48 cases (68.57%) of cesarean sections. Notably, the cesarean section rate in the research group was significantly higher than that in the control group, and the weeks of gestation at delivery and the birth weight of newborns in the research group were lower compared to those in the control group.

Our findings suggest that a deeper understanding of the relation between clinical changes and cardiac function in patients with pregnancy-induced hypertension syndrome can provide valuable insights into maternal and fetal prognosis. Effective clinical monitoring and timely intervention can lead to improved patient outcomes and ensure the safety of both the mother and child.

Study Limitations

This study has certain limitations that warrant consideration. Firstly, it was conducted at a single center, and the sample size was relatively small. Therefore, the generalizability of our findings to broader populations is limited. Furthermore, we acknowledge that there is room for improvement in controlling bias related to intervention factors, which could potentially affect the robustness of our study results. Considering these limitations, our research team is dedicated to mitigating bias and conducting more extensive and comprehensive investigations in the future, aiming to provide a more inclusive understanding of the topic.

CONCLUSION

This study highlights the substantial influence of pregnancy-induced hypertension on cardiac function and pregnancy outcomes. The differences observed in cardiac parameters and delivery methods emphasize the need for vigilant cardiac monitoring in cases of PIH. The early incorporation of advanced imaging techniques like 3D-STI can enhance detection capabilities. From a clinical perspective, this study underscores the significance of personalized care for PIH patients to optimize both cardiac health and maternal-fetal outcomes. These findings warrant further investigation to develop more effective interventions.

CONFLICT OF INTERESTS

The authors report no conflict of interest.

AVAILABILITY OF DATA AND MATERIALS

The data supporting the findings of this study are available from the corresponding author upon request, subject to reasonable conditions.

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AUTHOR CONTRIBUTIONS

Yan Wang and Hong'e Li made equal contributions.

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