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Original Research Article

A Comprehensive Review of Heart Rate Variability Changes in Pregnancy Induced Hypertension

Shabanam Rafik Shaha[1], Shah Navid Noorali[2], Ashutosh Jain[3], Jaya Jain[4]

[1]PhD Scholar, Dept. of Physiology, Index Medical College & Hospital, Indore, M.P.
[2]Professor & HOD, Dept. of Physiology, Arya Medical College & Hospital, Jaipur, Rajasthan.
[3]Professor, Dept. of Physiology, Index Medical College & Hospital, Indore, M.P.
[4]Professor & HOD, Dept. of Biochemistry, Index Medical College & Hospital, Indore, M.P.

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Corresponding author: Dr. Shabanam Rafik Shaha
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Abstract

Background: Patients with hypertensive pregnancy disorders often exhibit impaired regulation of the autonomic nervous system. HRV measurement provides a non-invasive method to assess autonomic control of the heart.

Objective: The objective was to determine if HRV is capable of detecting variations in autonomic nervous system activity between women with hypertensive pregnancy disorders and normotensive pregnant controls.

Methods: A comprehensive literature search was conducted in EMBASE, Medline, and the Cochrane CENTRAL database to identify studies evaluating HRV in PIH cases or those with a prior history of PIH, compared with normotensive pregnant women. The data is taken from original articles published 2016 onwards.

Results: The systematic search initially identified more than 50 publications, original & review articles of which 5 fulfilled the inclusion criteria. These studies involved a total of 150 women with hypertensive pregnancy disorders and 150 normotensive controls. Despite the variability in research, a consistent finding emerged: women with preeclampsia exhibited significantly reduced overall heart rate variability (HRV) compared with normotensive pregnant controls. In addition, several studies indicated a trend toward an increased low-frequency to high-frequency (LF/HF) ratio in women with preeclampsia, suggesting a relative shift toward sympathetic predominance.

Conclusion: Evidence from this review supports the concept that PIH & preeclampsia is marked by sympathetic hyperactivation in conjunction with parasympathetic withdrawal.

Keywords: HRV, PIH, Preeclampsia, LF/HF ratio.

Introduction

Pregnancy induced hypertension includes gestational hypertension, preeclampsia and eclampsia. 5–10% of all pregnancies are affected by it worldwide [1,2,3,4,5,6,7]. Hypertension is rise of blood pressure (systolic & diastolic) which remains sustained. systolic blood pressure 140 mmHg or more and/or diastolic blood pressure 90 mmHg or more [1,6,7,8,].

PIH typically develops after 20 weeks of pregnancy, where proteinuria (>300 mg/day) with raised blood pressure represents preeclampsia. It can present with vital organ dysfunction [6,7,8,9]. Previously diagnosed cases of hypertensive females when get conceived are called as cases of chronic hypertension with pregnancy [10]. Most frequently encountered clinically are the cases of PIH mainly gestational hypertension & preeclampsia [11,12]. Pregnancy induced hypertension remains one of the leading contributors to maternal and perinatal morbidity and mortality on a global scale [6,7,13]. Beyond pregnancy complications, PIH is increasingly recognized as predictors of heightened cardiovascular disease risk in affected women during later stages of life [14,15,16,19,20].

The precise etiological factors of PIH are not fully established; however, growing evidence suggests that the primary pathological alterations occur within the cardiovascular system [17,18,]. In normal pregnancy, the maternal circulation undergoes profound hemodynamic changes, including an increase in cardiovascular volume load and a reduction in pressure load, which serve as compensatory responses to the early gestational decline in peripheral vascular resistance [17,18]. These adaptations are critically regulated by the autonomic nervous system, which plays a pivotal

role in maintaining cardiovascular stability throughout pregnancy [21,22].

Pathophysiology Rationale: PIH are thought to arise from defective modification of the maternal spiral arteries in combination with inadequate cardiovascular adaptations to pregnancy, ultimately leading to elevated blood pressure and increased vascular resistance [18,19].

Several studies implicate dysfunction of the autonomic nervous system as a major factor in the development of PIH [12,17,18]. Cardiac autonomic function can be evaluated through heart rate variability (HRV) analysis, a widely recognized, non-invasive method [23,24]. HRV reflects the influence of both central and peripheral autonomic regulatory circuits on cardiovascular dynamics [24,25]. Therefore, abnormalities in HRV may serve as an indicator of autonomic nervous system dysfunction, providing insight into the pathophysiological mechanisms underlying Pregnancy Induced Hypertension [26].

Objective

To study HRV modulations indicating autonomic nervous system changes in women with PIH compared to normotensive pregnant women.

Methodology: Inclusion and Exclusion Criteria for Review on HRV in Preeclampsia.

Inclusion Criteria

Study Population

- Pregnant women diagnosed with preeclampsia (mild or severe), gestational hypertension, or PIH.
- Studies including control groups of normotensive pregnant women.

Study Design

- Original research articles: observational studies (cross-sectional, case-control, cohort).
- Longitudinal or continuous monitoring studies assessing HRV during pregnancy.

Outcome Measures

- Studies reporting Heart Rate Variability (HRV) as a measure of autonomic function.
- HRV assessed using time-domain (SDNN, RMSSD, pNN50), frequency-domain (LF, HF, LF/HF ratio).

Publication Characteristics

- Published in peer-reviewed journals.
- Full-text available in English language.
- Articles published from 2016 onwards (to include modern HRV analytic methods).

Relevance: Directly related to maternal autonomic function and HRV changes in preeclampsia.

Exclusion Criteria

Population

- Non-pregnant women, men, or studies exclusively in fetal HRV without maternal HRV data.
- Studies including mixed hypertensive disorders with primary hypertension with pregnancy & without separate reporting for preeclampsia.

Study Design

- Reviews, meta-analyses, editorials, conference abstracts, case reports.
- Animal studies, simulation studies, or in-vitro HRV research.

Outcomes

- Studies not reporting HRV indices separately (e.g., studies using only BP, HR, or baroreflex).
- HRV assessed but data not stratified by preeclampsia vs controls.

Publication Characteristics

- Articles not in English.
- Non-peer-reviewed publications.
- Grey literature, dissertations, or unpublished data.

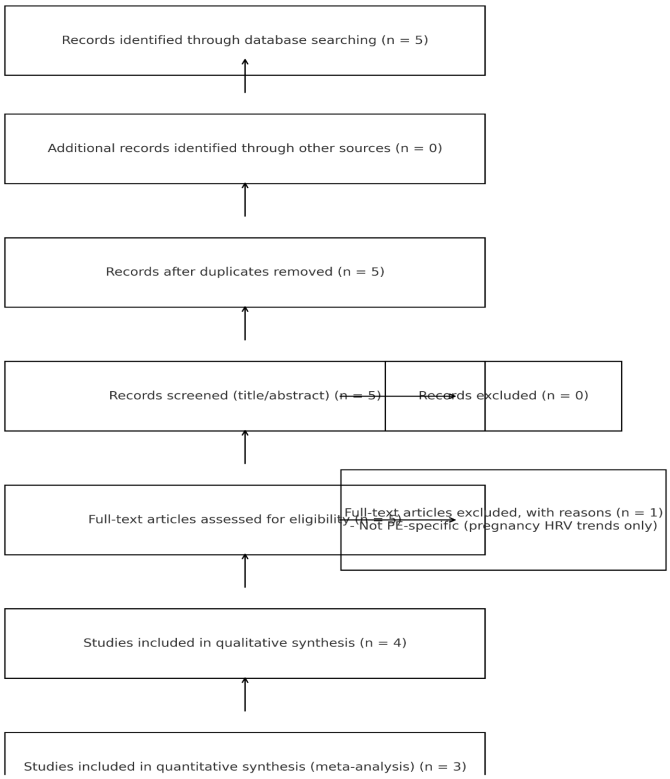

Figure 1: PRISMA Flow shows the search process in steps.

HRV definitions: Heart rate variability (HRV) refers to the fluctuations in time intervals between consecutive heartbeats, arising from the interplay of cardiac–neural mechanisms, hormonal influences, and autonomic pathways regulating the heart, vasculature, and renal system [24,25,26].

Electrocardiography (ECG) serves as the principal tool for HRV measurement, where derived data are interpreted by applying time and frequency-based analytical techniques [24].

Frequency-domain features: Frequency domain analysis of HRV evaluates the distribution of power across different frequency bands, reflecting autonomic regulation of the heart.

The low-frequency component is influenced by both sympathetic and parasympathetic activity, while the high-frequency band predominantly indicates parasympathetic (vagal) control. Ratios such as LF/HF are often used to estimate the balance between sympathetic and parasympathetic nervous system activity.

Table 1: Heart Rate Variability (HRV) Parameters and Their Physiological Significance

Domain	Parameter	Definition	Physiological Significance
Time-Domain Measures	SDNN (Standard Deviation of NN intervals)	Standard deviation of all normal-to-normal (NN) R-R intervals over a given period	Reflects overall autonomic variability; higher values indicate good adaptability, lower values suggest reduced autonomic flexibility.
	RMSSD (Root Mean Square of Successive Differences)	Square root of the mean squared differences between successive NN intervals	Marker of parasympathetic (vagal) activity; high RMSSD indicates stronger vagal tone.
	pNN50	Percentage of consecutive NN intervals differing by >50 ms	Indicator of parasympathetic modulation; often reduced in autonomic dysfunction.
	NN50	Absolute count of NN interval pairs differing by >50 ms	Similar to pNN50; evaluates short-term vagal activity.
	HR Max–Min	Difference between	Reflects overall autonomic

		maximum and minimum heart rate during a period	modulation; reduced variability is a marker of impaired autonomic function.
Frequency-Domain Measures	VLF (Very Low Frequency, <0.04 Hz)	Power in the very low-frequency range of HR oscillations	Associated with thermoregulation, hormonal and renin-angiotensin system influences.
	LF (Low Frequency, 0.04–0.15 Hz)	Power in the low-frequency band of HRV spectrum	Represents a mix of sympathetic and parasympathetic modulation; reflects baroreflex activity.
	HF (High Frequency, 0.15–0.40 Hz)	Power in the high-frequency band	Marker of parasympathetic (vagal) activity, closely linked to respiratory sinus arrhythmia.
Frequency-Domain Measures	LF/HF Ratio	Ratio of low-frequency to high-frequency power	Index of sympathovagal balance; higher values suggest sympathetic dominance, lower values suggest parasympathetic predominance.
	Total Power (TP)	Sum of power across all frequency bands (VLF, LF, HF)	Reflects overall HRV; reduction indicates poor autonomic adaptability or pathological stress.

Results

Table 2: PRISMA-Based Scoring: HRV Studies in PIH

Domain	Chaswal et al. (2018)	Hossen et al. (2017)	Musa et al. (2016)	Lakhno (2017)
Title & Abstract	2	2	2	2
Rationale & Objectives	2	2	2	2
Methods – Participants	2	1	2	2
Methods – HRV Assessment	2	2	2	2
Results – Baseline Data	2	2	2	2
Results – HRV Findings	2	2	2	2
Results – Statistical Analysis	2	2	2	2
Discussion – Key Results	2	2	2	2
Discussion – Implications	2	2	2	2
Ethics	2	2	2	2
Total (out of 20)	20	19	20	20

4 Original articles were reviewed which fulfilled the inclusion criteria.

These studies involved a total of 150 women with hypertensive pregnancy disorders and 150 normotensive controls. Considerable difference was evident across the included studies in terms of methodology and outcome measures. Despite this variability, a consistent finding emerged: women with preeclampsia exhibited significantly reduced overall heart rate variability (HRV) compared with normotensive pregnant controls.

In addition, studies indicated a trend toward an increased low-frequency to high-frequency (LF/HF) ratio in women with preeclampsia, suggesting a relative shift toward sympathetic predominance.

Table 3: results of HRV Measures in Preeclampsia (Time & Frequency Domain)

Study	Time-Domain Measures (SDNN, RMSSD, pNN50, NN50)	Frequency-Domain Measures (VLF, LF, HF, LF/HF Ratio, TP)	Key Findings & Interpretation
Chaswal et al. (2018)	↓ SDNN, ↓ RMSSD, ↓ pNN50 → overall reduction in variability	↓ HF, ↓ LF, ↑ LF/HF ratio → sympathetic predominance	Preeclampsia shows reduced parasympathetic tone and overall variability, with shift toward sympathetic dominance.
Hossen et al. (2017)	Not primary focus; limited time-domain reporting	↓ HF power, ↓ LF power, altered wavelet-based indices	Spectral HRV analysis distinguished PE from controls; findings suggest general autonomic imbalance with reduced HRV power spectrum.
Musa et al. (2016)	↓ SDNN, ↓ RMSSD, ↓ pNN50 → marked fall in time-domain indices	↓ HF, ↓ LF, ↑ LF/HF ratio → sympathetic overactivity	Strong evidence of autonomic dysregulation in PE, with reduced vagal activity and higher sympathetic drive.
Lakhno (2017)	↓ SDNN and RMSSD (maternal HRV)	↓ HF, ↓ LF, ↑ LF/HF ratio; fetal HRV also reduced	Demonstrated maternal and fetal autonomic imbalance in PE, indicating circulatory compromise affecting both mother and fetus.

HRV changes in PIH: Notable reduction in overall HRV was observed in women with preeclampsia compared with normotensive pregnant controls. [27]

In particular, women with moderate preeclampsia tended to exhibit a higher LF/HF ratio relative to normotensive pregnancies, suggesting a shift toward sympathetic predominance.[28] Supporting this, these studies reported an increased LF/HF ratio in women who developed PIH, indicating that autonomic imbalance may precede the clinical manifestation of the disorder. [27,28]

Discussion

HRV in Hypertensive Pregnancy Disorders: This comprehensive review supports the existing evidence on heart rate variability (HRV) in PIH. The findings related to frequency-domain indices were consistent across studies, even though there was heterogenecity in study populations, methodology, and analytical approaches.

Specially, results for normalized low-frequency (LF) and high-frequency (HF) components demonstrated greater consistency. Among pregnant women with preeclampsia, three of the four available studies reported elevated LF/HF ratio. Taken together, these findings indicate a trend toward sympathetic over activity and diminished parasympathetic tone in PIH, although variability in frequency-domain parameters underscores the need for methodological standardization across future studies.[29]

Conclusion

This comprehensive study supports the hypothesis that sympathetic overdrive & parasympathetic withdrawal is associated with pregnancy induced hypertension. However, the included studies in our review showed large diversity in the methods applied.

Highlights

- Autonomic nervous system changes are frequently observed in individuals with PIH.
- Measurement of HRV provides information about autonomic control of the cardiovascular system.
- Overall heart rate variability was significantly lower in preeclampsia than in healthy pregnant controls.
- An upward shift in the LF/HF ratio has been noted in cases of preeclampsia.
- Autonomic imbalance in PIH is characterized by sympathetic predominance and diminished parasympathetic activity.
- Heart rate variability in hypertensive pregnancy disorders has been explored through a systematic review.

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