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RESEARCH ARTICLE
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INVESTIGATING HEMODYNAMIC CHANGES AND HEART RATE VARIABILITY IN DIABETIC PATIENTS DURING ANESTHESIA INDUCTION

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Abstract
Background: The relationship between heart rate variability and diabetes is well established, with studies showing that reduced HRV is a predictor of diabetic autonomic neuropathy and cardiovascular morbidity. Decreased HRV is associated with an increased risk of arrhythmias, myocardial infarction, and overall mortality in diabetic patients.
Methodology: On the day prior to surgery, patients underwent a 10-minute heart rate variability (HRV) assessment, after resting for 10 minutes with their eyes open during the recording. The HRV analysis included both time-domain and frequency-domain parameters: Hemodynamic parameters measurements were taken at several intervals: pre-induction, post-induction, post-intubation, and every 3 minutes for the next 15 minutes.
Results: Diabetic individuals exhibited a higher tendency to develop bradycardia compared to non-diabetics. Additionally, the decrease in heart rate after induction was more pronounced in the diabetic group than in the non-diabetic group. A decrease in MAP was observed in both groups after induction. However, diabetic individuals had a comparatively lower MAP than non-diabetics, particularly after induction and post-intubation. The difference was statistically significant at 12 and 15 minutes post-intubation ($p = 0.04$).
Conclusion: The findings suggest that preoperative HRV assessments could help predict cardiovascular responses and guide individualized anesthesia strategies. Given the potential risks associated with altered autonomic regulation in this population, tailored perioperative management is essential to ensure better outcomes.

Keywords: Hemodynamic Changes, Heart Rate Variability, Diabetic Patients, Anesthesia Induction

INTRODUCTION:
Anesthesia induction is a critical period during surgery when cardiovascular stability is paramount. For diabetic patients, alterations in hemodynamic parameters and heart rate variability (HRV) during anesthesia induction may pose distinct challenges due to the underlying pathophysiology of the disease.

Hemodynamic stability, which involves the maintenance of adequate blood pressure, heart rate, and cardiac output, is essential during the induction of anesthesia. In diabetic patients, however, there are concerns regarding both pre-existing cardiovascular autonomic dysfunction and the potential for exacerbation of these abnormalities under anesthesia. Diabetes is associated with several cardiovascular complications, including diabetic cardiomyopathy, atherosclerosis, and autonomic neuropathy, which may affect the hemodynamic response to anesthetic agents.

Autonomic neuropathy in particular is a common complication in long-standing diabetes. This condition impairs the sympathetic and parasympathetic regulation of cardiovascular function, which plays a key role in responding to the stressors of anesthesia induction.[1] Normally, the sympathetic nervous system increases heart rate and blood pressure in response to anesthetic agents, while the parasympathetic nervous system acts to counterbalance these effects. However, in patients with autonomic neuropathy, this delicate balance is disrupted, often leading to exaggerated or blunted cardiovascular responses.[2] This disruption may result in hypotension or abnormal heart rate responses, which can be exacerbated during anesthesia induction due to the vasodilatory effects of anesthetic agents such as propofol and sevoflurane .[3]

Heart rate variability (HRV) is a non-invasive marker of autonomic nervous system function and has been widely used to assess the balance between the sympathetic and parasympathetic branches. It is defined as the variation in the time intervals between consecutive heartbeats and is influenced by multiple factors, including age, gender, and underlying health conditions. [4] In the context of diabetes, HRV is often reduced due to the impairment of autonomic control over the heart.

The relationship between HRV and diabetes is well established, with studies showing that reduced HRV is a predictor of diabetic autonomic neuropathy and cardiovascular morbidity. [5]

Decreased HRV is associated with an increased risk of arrhythmias, myocardial infarction, and overall mortality in diabetic patients. [6] Furthermore, HRV can provide insight into how the autonomic nervous system responds to various stimuli, including the induction of anesthesia. As the autonomic nervous system is directly involved in regulating heart rate and blood pressure, changes in HRV during anesthesia induction can reflect the degree of autonomic dysfunction in diabetic patients.

Anesthesia induction in diabetic patients requires careful consideration of their altered cardiovascular physiology. In addition to autonomic dysfunction, diabetes can affect the pharmacokinetics and pharmacodynamics of anesthetic drugs. For instance, insulin resistance and altered glucose metabolism can impact the patient's response to glucose-insulin-potassium infusions used to manage anesthesia-induced hyperkalemia.[7] Furthermore, the risk of hypoglycemia is heightened during surgery, necessitating careful monitoring and management of blood glucose levels.

Given the prevalence of diabetes and the associated cardiovascular risks, understanding the hemodynamic changes and HRV alterations in diabetic patients during anesthesia induction is essential for anesthesiologists. The objectives of the study were to evaluate and contrast the autonomic function between diabetic and non-diabetic patients before surgery, using heart rate variability as a measure and to examine the hemodynamic responses of diabetic and non-diabetic patients during the induction phase of general anesthesia .

MATERIAL & METHODS:

A cross-sectional study was carried out in a tertiary care hospital in North India over a period of six months from September 2024 to February 2025. A total of 80 study subjects were selected 40 in each Diabetic and Non-diabetic group using prevalence from the previous study done by Dinesh et. al [8] in similar settings.

Inclusion & Exclusion Criteria:

Patients aged more than 40 years of age with duration of diabetes less than 10 years, Scheduled for elective surgeries under general anesthesia with BMI less than 30 kg/m^2 were included in the study. However patients with a history of cardiovascular, respiratory, or cerebrovascular disease, patients currently on beta-blockers, calcium channel blockers, or angiotensin-converting enzyme inhibitors with a heart rate below 50 beats per minute and those not willing to participate were excluded from the study.

Methodology:

HRV Testing Procedure

On the day prior to surgery, patients underwent a 10-minute heart rate variability (HRV) assessment, after resting for 10 minutes with their eyes open during the recording. The HRV was measured using the PowerLab 15T system with LabChart software from ADInstruments (ADInstruments Ltd, UK). A Lead II electrocardiogram (ECG) was used for data collection and HRV analysis.

HRV Analysis

The HRV analysis included both time-domain and frequency-domain parameters:

- **Time-domain variables:**
  - **SDNN** (Standard Deviation of NN intervals, representing the square root of the variance),
  - **RMSSD** (Root Mean Square of Successive Differences, representing the square root of the mean sum of squared differences between adjacent NN intervals),
  - **NN50** (Number of successive NN intervals differing by more than 50 ms, calculated as the square root of the mean squared difference between successive NN intervals).
- **Frequency-domain variables:**
  - **TP** (Total Power),
  - **LF** (Low-frequency power),
  - **HF** (High-frequency power),
  - **LF/HF Ratio** (the ratio of low-frequency to high-frequency power).

Preoperative and Intraoperative Procedures

On the day of surgery, patients were preloaded with 500 mL of Ringer's lactate solution in the preoperative area, then transferred to the operating room. ASA standard monitors were applied, and baseline vital signs were recorded. Blood glucose levels were checked using the Accu-Check Active blood glucose monitoring system prior to anesthesia induction.

Patients were pre-oxygenated with 100% oxygen for 3 minutes. The induction of anesthesia was consistent across all participants, beginning with an intravenous administration of fentanyl (2 mcg/kg). Propofol was titrated until loss of response to verbal commands (administered over a span of 30-60 seconds), followed by muscle relaxation with vecuronium (0.1 mg/kg). This was followed by mask ventilation, and endotracheal intubation was performed using an appropriately sized cuffed endotracheal tube. Positive pressure ventilation was adjusted to achieve an end-tidal carbon dioxide level of 28-32 mm Hg and peak airway pressures of less than 25 cm H2O, with a positive end-expiratory pressure (PEEP) of 5 cm H2O. Anesthesia maintenance was carried out with a 50:50 mixture of O2 and N2O, and sevoflurane was titrated to a minimum alveolar concentration (MAC) of 1.0.

Hemodynamic Monitoring

The following hemodynamic parameters were recorded: heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure (MAP). These measurements were taken at several intervals: pre-induction, post-induction, post-intubation, and every 3 minutes for the next 15 minutes.

Definitions and Management of Hypotension and Bradycardia

- **Hypotension** was defined as a MAP less than 60 mm Hg or a decrease of more than 20% from the baseline MAP.
- **Bradycardia** was defined as a heart rate below 50 beats per minute or a reduction of more than 20% from the baseline heart rate.

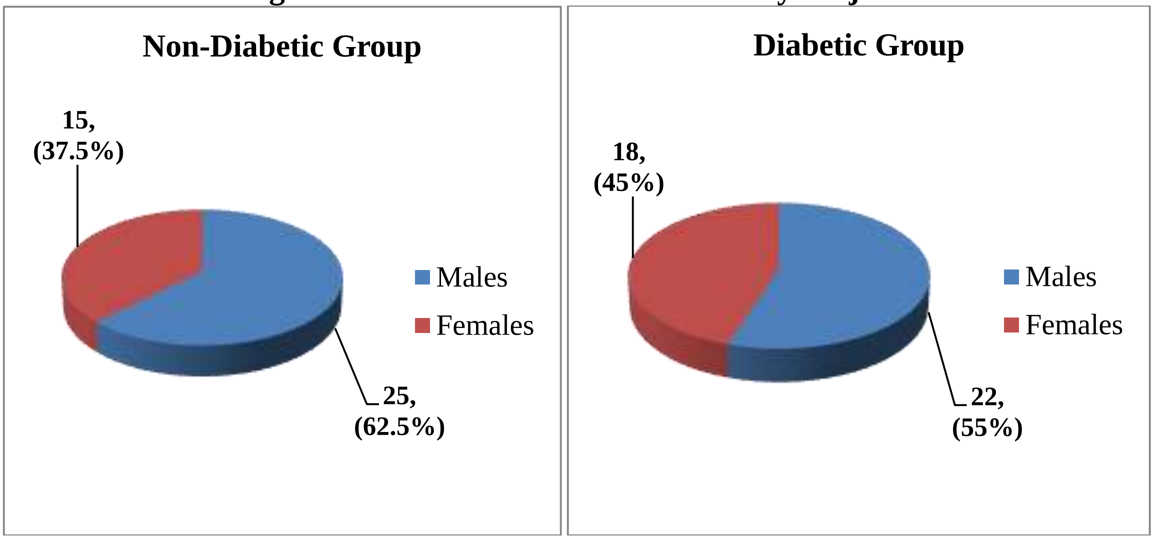
In cases of hypotension, **ephedrine** 6 mg was administered intravenously, and for bradycardia, **atropine** 0.6 mg was given intravenously.

Statistical analysis:

Statistical analysis was performed using SPSS version 21.0.Docio-demographic distribution was compared using the chi-square test, while a Student's paired t-test assessed differences in height, weight, and BMI between diabetic and non-diabetic groups. A p-value ≤ 0.05 was considered significant.

RESULTS:

Fig. 1: Gender wise distribution of study subjects



A total of 40 study subjects were selected in each group. Non-Diabetic group comprised of 25 males and 15 females while diabetic group have a higher females proportion (18) and 22 were males.

Table 1: Age and BMI distribution of study groups

Parameters	Group A (Non-Diabetic)	Group B (Diabetic)	p value
Mean age ± SD (in years)	42.56 ± 16.72	43.87 ±17.21	0.513
BMI (Mean ± SD in Kg/m^2)	23.45 ± 3.17	24.13 ± 3.89	0.345

Mean age and BMI was slightly higher in diabetic group as compared to Non-Diabetic group, although it was not statistically significant.

Table 2: Mean time and frequency domain analysis of Heart Rate variability

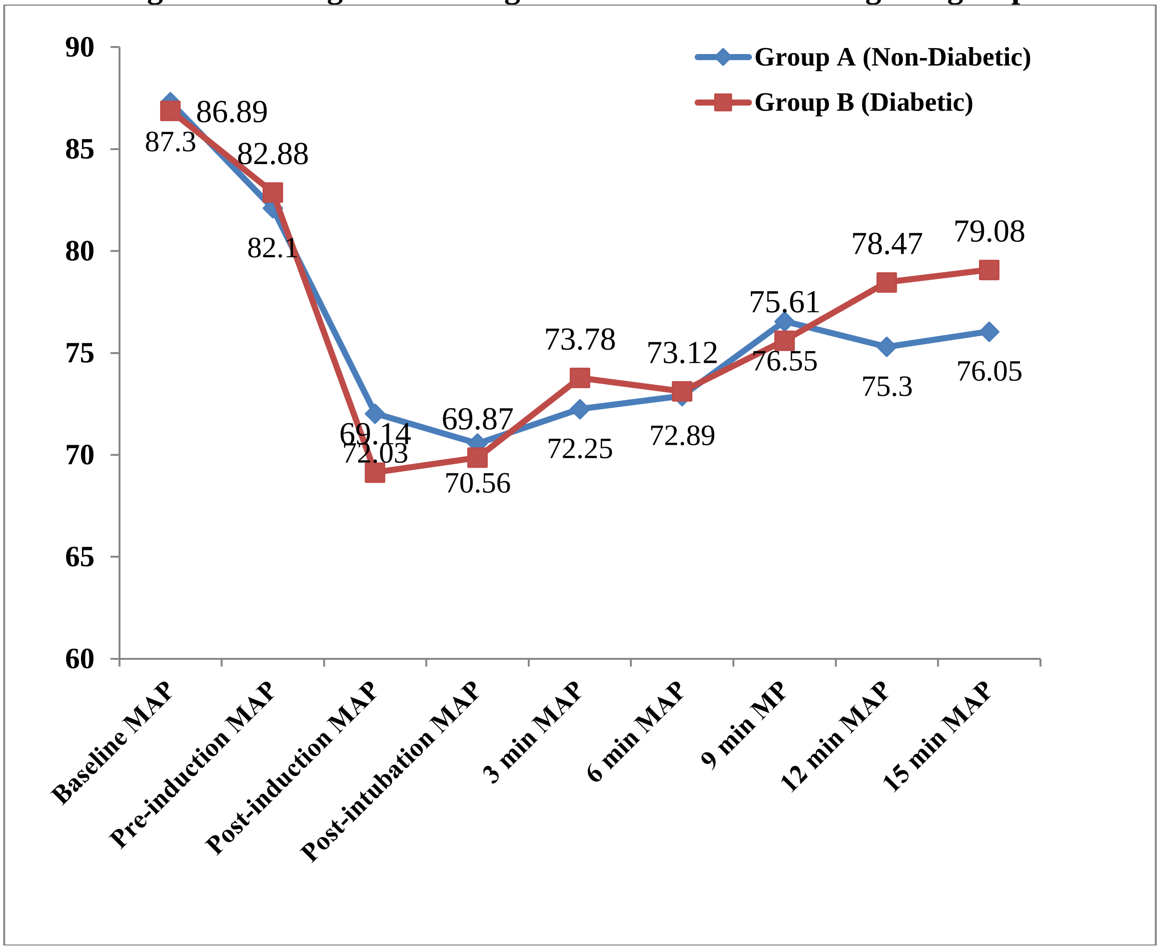
Variable	Group A (Non-Diabetic)	Group B (Diabetic)	p value
SDNN (in ms)	145.22± 57.91	149.89± 67.55	0.401
RMSSD (in ms)	79.11±110.12	86.42±125.67	0.398
Total power (in ms^2)	2601.45±1132.72	1798.67±1391.23	*0.002**
Low Frequency Power (in ms^2)	947.11±653.55	940.14±601.35	0.511
High Frequency Power (in ms^2)	932.33±1051.78	946.78±502.15	0.394
Low Frequency Power (normalized units)	44.57±13.30	41.95±19.12	0.291
High Frequency Power (normalized units)	32.50±8.94	36.12±14.56	0.204
LF/HF ratio	1.27	1.19	0.301

**p value significant*

SDNN is Standard Deviation of Normal-to-Normal interbeat intervals measured in milliseconds. RMSSD is Root Mean Square of Successive Differences between normal heartbeats measured in milliseconds.

Table 2 presents the mean time and frequency domain analysis of Heart Rate Variability (HRV) for non-diabetic (Group A) and diabetic (Group B) individuals. The time domain measures, including SDNN (Standard Deviation of NN intervals) and RMSSD (Root Mean Square of Successive Differences), show no significant differences between the two groups ($p > 0.05$). Similarly, the frequency domain measures for low-frequency (LF) and high-frequency (HF) power in ms^2 and their normalized units also do not exhibit significant differences ($p > 0.05$). However, a significant difference is observed in **total power**, with Group A showing higher total power (2601.45 ± 1132.72 ms^2) compared to Group B (1798.67 ± 1391.23 ms^2), with a p-value of 0.002, indicating reduced overall HRV in diabetic individuals. The **LF/HF ratio**, a marker of autonomic balance, does not show a significant difference between groups ($p = 0.301$). These results suggest subtle changes in HRV, especially in total power, among diabetic individuals.

Fig. 2: Line diagram showing trend in heart rate among two groups



Diabetic individuals exhibited a higher tendency to develop bradycardia compared to non-diabetics. Additionally, the decrease in heart rate after induction was more pronounced in the diabetic group than in the non-diabetic group.

Table 3: Heart rate variability (HRV) among two groups

Variable	Group A (Non-Diabetic)	Group B (Diabetic)
Baseline MAP	87.3	86.89
Pre-induction MAP	82.1	82.88
Post-induction MAP	72.03	69.14
Post-intubation MAP	70.56	69.87
3 min MAP	72.25	73.78
6 min MAP	72.89	73.12
9 min MP	76.55	75.61
12 min MAP	75.3	78.47
15 min MAP	76.05	79.08

The data shows slight differences in MAP between the two groups across the various time points, but these differences are not substantial. At baseline, pre-induction, and post-induction, the MAP values are very similar between the two groups. After intubation, the MAP decreases slightly in both groups. Throughout the 15-minute observation period (3 to 15 minutes), MAP values remain relatively stable for both groups, with Group B showing a slightly higher MAP at some points.

Table 4: Comparison of Mean Arterial Pressure (MAP) trends between the two groups

Variable	Group A (Non-Diabetic)	Group B (Diabetic)	p value
Baseline MAP	88.56	93.16	0.07
Pre-induction MAP	86.79	87.91	0.28
Post-induction MAP	74.25	74.76	0.45
Post-intubation MAP	71.22	72.43	0.19
3 min MAP	75.66	76.23	0.29
6 min MAP	77.90	76.05	0.17
9 min MP	78.15	76.70	0.22
12 min MAP	78.90	77.11	*0.04**
15 min MAP	79.20	77.85	*0.04**

p value significant

A decrease in MAP was observed in both groups after induction. However, diabetic individuals had a comparatively lower MAP than non-diabetics, particularly after induction and post-intubation. The difference was statistically significant at 12 and 15 minutes post-intubation (p = 0.04).

DISCUSSION:

Autonomic Dysfunction in Diabetic Patients:

The autonomic nervous system (ANS) plays a crucial role in regulating heart rate, blood pressure, and overall cardiovascular function, especially during periods of stress such as anesthesia induction. In healthy individuals, the sympathetic and parasympathetic branches of the ANS work together to maintain cardiovascular homeostasis. However, in diabetic patients, particularly those with long-standing or poorly controlled diabetes, autonomic dysfunction is common. This dysfunction primarily manifests as impaired parasympathetic function and reduced heart rate variability, which is a marker of the autonomic regulation of heart rate as quoted by Ewing et al. [6] in their study.

In this study, the comparison of HRV between diabetic and non-diabetic patients preoperatively revealed significantly lower HRV in the diabetic group. Reduced HRV is a well-established indicator of autonomic neuropathy in diabetes and reflects an imbalance in sympathetic and parasympathetic activity as seen in findings of Stein et al. in 2005.[9] The findings are consistent with previous studies that show a clear reduction in HRV in diabetic patients due to autonomic dysfunction, which can impair their ability to respond to the physiological stressors of anesthesia induction as found by Figueroa et al. in 2011.[10] These results highlight the importance of assessing HRV in diabetic patients to gauge autonomic function and tailor perioperative management strategies.

Hemodynamic Changes During Anesthesia Induction:

The second objective of this study was to examine the hemodynamic responses of diabetic and non-diabetic patients during anesthesia induction. In general, anesthesia induction involves the administration of agents such as propofol, sevoflurane, or thiopental, which can cause vasodilation and a subsequent drop in blood pressure. In non-diabetic individuals, compensatory mechanisms involving sympathetic activation typically maintain stable blood pressure and heart rate. However, in diabetic patients, particularly those with autonomic neuropathy, these compensatory mechanisms are often impaired as also quoted by Moll et al. in 2011.[11] This study observed that diabetic patients experienced more pronounced drops in blood pressure and heart rate during anesthesia induction compared to non-diabetic controls, which may be attributed to impaired sympathetic nervous system function. This is in line with previous reports suggesting that diabetic patients are more prone to intraoperative hypotension, which can lead to ischemic events and other complications (Pasquel et al., 2016). [2]

In addition to autonomic dysfunction, diabetes-related vascular changes, including endothelial dysfunction and increased arterial stiffness, can further exacerbate hemodynamic instability during anesthesia induction as seen in findings of Ziegler et al in 2009. [12] These changes impair the ability of blood vessels to dilate and constrict appropriately in response to anesthetic agents, contributing to the observed hemodynamic fluctuations. Studies have shown that diabetic patients are at higher risk for both hypotension and cardiovascular events during the perioperative period, emphasizing the need for close monitoring and proactive management of their hemodynamic status (Baguley et al., 2015).[3]

Role of Heart Rate Variability as a Predictor:

Heart rate variability is a valuable tool for assessing autonomic function and predicting hemodynamic responses during the perioperative period. In diabetic patients, reduced HRV has been associated with an increased risk of cardiovascular events, including arrhythmias, myocardial infarction, and mortality (Stein et al., 2005). [10] The findings of this study support the notion that HRV may serve as an important predictor of hemodynamic instability in diabetic patients undergoing anesthesia. As HRV reflects the balance between sympathetic and parasympathetic activity, a low HRV can signal a reduced ability to respond to stressors such as anesthesia induction. This has important clinical implications, suggesting that preoperative HRV assessments could help anesthesiologists predict which patients may experience significant hemodynamic fluctuations and guide the selection of anesthetic agents or the use of adjunct medications to stabilize blood pressure and heart rate.

Anesthesia Management in Diabetic Patients:

Given the results of this study, it is evident that diabetic patients require special consideration during anesthesia induction. The autonomic dysfunction and hemodynamic instability observed in this population necessitate tailored anesthetic management strategies. Monitoring HRV during the perioperative period could provide real-time insights into autonomic function, enabling anesthesiologists to adjust anesthetic agents and interventions accordingly. Furthermore, using anesthetic agents with minimal cardiovascular effects, such as etomidate or ketamine, may help mitigate hemodynamic fluctuations in diabetic patients (Moll et al., 2011). [11] Additionally, ensuring optimal glycemic control preoperatively and during the perioperative period is essential to reduce the risk of hypoglycemia and other complications that could further exacerbate hemodynamic instability.

Limitations:

The findings from the study may not be generalize across all diabetic patients, as the results may vary with different types and durations of diabetes as well as owing to small sample size. Additionally, the study may not account for all potential confounding factors, such as the presence of comorbidities (e.g., hypertension, coronary artery disease) or variations in diabetes control, which can influence both autonomic function and hemodynamic responses. Furthermore, the assessment of HRV is influenced by several external factors, including patient anxiety, physical activity, and medication use, which may not have been controlled for. Also the differences in anesthesia protocols or the use of various anesthetic agents could introduce variability in the findings.

Recommendations:

Based on the findings of this study, it is recommended that further research with a larger, more diverse sample size be conducted to enhance the generalizability of the results. Future studies should also control for potential confounders, such as comorbidities, medication use, and variations in diabetes management, to better isolate the effects of diabetes on hemodynamic and HRV responses. Additionally, incorporating continuous HRV monitoring during the perioperative period could provide more comprehensive insights into autonomic function changes.

CONCLUSION:

Diabetic patients demonstrate altered autonomic function and may experience greater hemodynamic fluctuations, posing challenges for anesthetic management. The findings suggest that preoperative HRV assessments could help predict cardiovascular responses and guide individualized anesthesia strategies. Given the potential risks associated with altered autonomic regulation in this population, tailored perioperative management is essential to ensure better outcomes.

Conflict of interest: None

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