Volume 4, Issue 3, 2026

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

INCIDENCE AND HEMODYNAMIC RESPONSE OF TRIGEMINOCARDIAC REFLEX DURING TRIGEMINAL NERVE MANIPULATION IN MICROVASCULAR DECOMPRESSION SURGERY

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DOI: https://doi.org/10.5281/zenodo.21903190

Keywords

Trigeminocardiac reflex; Microvascular decompression; Trigeminal nerve; Hemodynamic instability; Neurosurgical anesthesia; Brainstem reflex

Article History

Received: 11 January 2026
Accepted: 24 February 2026
Published: 10 March 2026

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Abstract

The trigeminocardiac reflex (TCR) is a brainstem reflex elicited by stimulation of the trigeminal nerve, characterized by sudden bradycardia, hypotension, and occasionally asystole. Although frequently reported during skull base procedures, its incidence and detailed hemodynamic patterns during microvascular decompression (MVD) remain insufficiently quantified.

Objective

To determine the incidence, hemodynamic characteristics, and perioperative predictors of TCR during trigeminal nerve manipulation in MVD surgery.

Methods

A prospective observational study was conducted on 128 adult patients undergoing MVD for trigeminal neuralgia. Continuous intraoperative hemodynamic monitoring was performed. TCR was defined as a ≥20% decrease in heart rate and/or mean arterial pressure from baseline coinciding with trigeminal nerve manipulation. Multivariable logistic regression was used to identify independent predictors.

Results

A total of 128 patients undergoing first-time microvascular decompression for classical trigeminal neuralgia were analyzed. Intraoperative trigeminocardiac reflex (TCR) occurred in 41 patients, yielding an incidence of 32.0% (95% CI: 24.1–40.8%). TCR episodes were observed exclusively during trigeminal nerve manipulation and were reversible in all cases. Mean heart rate decreased from 72.4 ± 9.1 bpm to 47.3 ± 8.6 bpm ($p < 0.001$), and mean arterial pressure decreased from 86.7 ± 10.2 mmHg to 61.6 ± 9.8 mmHg ($p < 0.001$) during reflex episodes. Severe TCR occurred in 9.4% of patients and was associated with greater hemodynamic depression. Cisternal trigeminal nerve manipulation was the strongest independent predictor of TCR (OR 2.71, 95% CI 1.31–5.63; $p = 0.007$), while deeper anesthetic depth was protective (OR 0.62, 95% CI 0.39–0.97; $p = 0.039$).

Discussion

This study demonstrates that TCR occurs in approximately one-third of patients undergoing MVD, consistent with higher-end estimates reported in skull base literature. The magnitude of hemodynamic depression observed underscores the clinical relevance of this reflex.

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ISSN: (e) 3007-1607 (p) 3007-1593

Cisternal manipulation emerged as the strongest independent predictor, supporting the anatomical basis of TCR involving high-density sensory fibers near the root entry zone. The protective association of deeper anesthesia aligns with experimental data suggesting suppression of brainstem reflex arcs.

Conclusion

Trigeminocardiac reflex is a common and clinically significant intraoperative event during microvascular decompression for trigeminal neuralgia. Typically transient and reversible, its occurrence is strongly influenced by the site of trigeminal nerve manipulation and anesthetic depth. Awareness of high-risk surgical phases and optimization of anesthetic management may reduce the severity of hemodynamic disturbances.

INTRODUCTION

The trigeminocardiac reflex (TCR) is a well-recognized brainstem reflex characterized by sudden parasympathetically mediated cardiovascular depression following stimulation of the trigeminal nerve or its central connections. Originally described in the context of maxillofacial surgery, the reflex has since been increasingly reported during a wide spectrum of neurosurgical procedures involving the skull base and posterior fossa. Contemporary definitions describe TCR as an abrupt decrease of at least 20% in heart rate and/or arterial blood pressure temporally associated with trigeminal nerve stimulation, with resolution upon cessation of the triggering stimulus (Schaller et al., 2009; Meuwly et al., 2017).

Microvascular decompression (MVD) remains the definitive surgical treatment for medically refractory classical trigeminal neuralgia, offering durable pain relief by alleviating neurovascular conflict at the root entry zone of the trigeminal nerve. However, this anatomical region represents a critical afferent limb of the TCR pathway, rendering MVD particularly susceptible to reflex activation. Previous studies have largely been limited to case reports, small retrospective series, or heterogeneous skull base cohorts, with reported TCR incidence ranging from 8% to over 40%, reflecting substantial methodological variability (Lang et al., 2012; Chowdhury et al., 2015).

The hemodynamic consequences of TCR during MVD may range from transient, clinically inconsequential bradycardia to profound hypotension and asystole, posing immediate risks to cerebral perfusion and surgical safety. Despite these implications, there remains a lack of prospective, procedure-specific data characterizing the incidence, severity, and predictors of TCR during MVD. The influence of anesthetic depth, site of nerve manipulation, and patient-specific autonomic factors remains incompletely understood. The present study was therefore designed to systematically evaluate the incidence and hemodynamic profile of TCR during trigeminal nerve manipulation in MVD surgery, to identify independent perioperative predictors, and to contextualize these findings.

METHODS

Study Design and Setting

Prospective observational study, was conducted at the Department of Neurosurgery and Anesthesiology, Mardan Medical Complex, Mardan, Pakistan.

Duration

The study was conducted, from **July 2025 to January 2026.**

Ethical Approval

Institutional Review Board approval was obtained from and written informed consent was obtained from all participants.

Sample Size

Prior observational studies and narrative reviews have documented TCR incidence rates ranging from approximately 20% to 40%, depending on the surgical approach, anatomical site of stimulation, and definition applied (Schaller, 2004; Schaller et al., 2009; Spiriev et al., 2011; Dellaretti et al., 2008). Specifically, reports focusing on cerebellopontine angle and microvascular decompression surgery have consistently demonstrated clinically relevant rates of reflex occurrence within this range (Koerbel et al., 2005; Arasho et al., 2009; Chowdhury et al., 2015). Assuming an expected

TCR incidence of approximately 30%, consistent with prior neurosurgical series and contemporary reviews (Meuwly et al., 2017; Sandu et al., 2015), a confidence level of 95%, and margin of error 5 %, by WHO sample size calculator the sample size was calculated to be 128 patients.

Patient Selection

Inclusion Criteria

- Age ≥18 years
- Diagnosis of classical trigeminal neuralgia
- Scheduled for first-time MVD

Exclusion Criteria

- Prior posterior fossa surgery
- Pre-existing arrhythmias
- Pacemaker dependency

Anesthetic and Surgical Protocol

All patients underwent standardized general anesthesia with propofol–remifentanil total intravenous anesthesia. Trigeminal nerve manipulation phases were time-stamped and correlated with hemodynamic data.

Definition of TCR

TCR was defined as a ≥20% reduction in heart rate and/or mean arterial pressure from baseline occurring during trigeminal nerve manipulation and resolving after cessation of stimulus.

Data Collection

Demographic data, comorbidities, anesthetic parameters, and intraoperative hemodynamic variables were prospectively recorded. Heart rate and arterial pressure were continuously monitored and automatically logged at 5-second intervals throughout the procedure.

Statistical Analysis

Continuous variables were expressed as mean ± SD. Categorical variables were analyzed using χ^2 test. Paired t-tests compared baseline and event hemodynamics. Multivariable logistic regression identified independent predictors. A p-value <0.05 was considered statistically significant. Analyses were performed using SPSS v26.

RESULTS

A total of 128 patients undergoing first-time microvascular decompression for classical trigeminal neuralgia were included in the final analysis. The mean age of the study was 56.2 ± 11.4 years (range 31–78 years), with a predominance of female patients (79/128, 61.7%). Baseline cardiovascular parameters, anesthetic techniques, and comorbidity profiles were comparable between patients who developed trigeminocardiac reflex (TCR) and those who did not. No statistically significant differences were observed in baseline heart rate, mean arterial pressure, or use of beta-blockers between groups (Table 1).

Table 1. Baseline Demographic and Clinical Characteristics

Variable	TCR Group (n = 41)	Non-TCR Group (n = 87)	p-value
Age (years)	55.8 ± 10.9	56.4 ± 11.7	0.78
Female sex, n (%)	26 (63.4)	53 (60.9)	0.78
Baseline HR (bpm)	71.9 ± 9.3	72.7 ± 8.9	0.64
Baseline MAP (mmHg)	87.1 ± 10.6	86.5 ± 10.0	0.75
Hypertension, n (%)	15 (36.6)	29 (33.3)	0.71

Incidence of Trigeminocardiac Reflex

Intraoperative TCR was observed in 41 of 128 patients, yielding an overall incidence of 32.0% (95% CI: 24.1–40.8%). Reflex episodes occurred exclusively during direct trigeminal nerve manipulation and resolved following cessation of the stimulus. Based on predefined hemodynamic criteria, 22 patients (17.2%) experienced mild TCR, 7 patients (5.5%) moderate TCR, and 12 patients (9.4%) severe

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ISSN: (e) 3007-1607 (p) 3007-1593

TCR. No episode necessitated termination of the surgical procedure.

Hemodynamic Changes Associated With TCR
Patients experiencing TCR demonstrated pronounced and statistically significant hemodynamic depression compared with baseline values. Mean heart rate decreased from 72.4 ± 9.1 beats per minute (bpm) at baseline to a nadir of 47.3 ± 8.6 bpm during reflex episodes, corresponding to a mean relative reduction of 34.6% ± 9.8% ($p < 0.001$). Mean arterial pressure decreased from 86.7 ± 10.2 mmHg to 61.6 ± 9.8 mmHg, representing a mean reduction of 28.9% ± 11.2% ($p < 0.001$) (Table 2).

Table 2. Hemodynamic Parameters During TCR Episodes

Parameter	Baseline	TCR Nadir	Mean % Change	p-value
Heart rate (bpm)	72.4 ± 9.1	47.3 ± 8.6	−34.6 ± 9.8	<0.001
Mean arterial pressure (mmHg)	86.7 ± 10.2	61.6 ± 9.8	−28.9 ± 11.2	<0.001

Severe TCR episodes were associated with significantly greater reductions in both heart rate and arterial pressure compared with mild and moderate forms ($p < 0.001$). Transient sinus pauses were observed in three patients (2.3% of total cohort), all of which resolved spontaneously without pharmacologic intervention.

Temporal Relationship to Surgical Manipulation
Analysis of time-stamped surgical events demonstrated that TCR incidence was significantly higher during manipulation of the cisternal segment of the trigeminal nerve compared with peripheral or dural handling (41.8% vs. 18.9%, $p = 0.006$). Reflex onset occurred within a median of 6 seconds (interquartile range 4–9 seconds) following initiation of nerve traction.

Sensitivity Analyses
Patients with higher baseline vagal tone, estimated using pre-induction heart rate variability indices, exhibited a significantly increased incidence of TCR (38.9% vs. 24.5%, $p = 0.018$). Sensitivity analyses applying alternative TCR definitions (≥25% and ≥30% reduction in heart rate and/or mean arterial pressure) yielded consistent incidence rates and predictor significance, confirming the robustness of the primary analysis.

Multivariable Predictors of TCR
On multivariable logistic regression analysis adjusting for age, sex, baseline cardiovascular parameters, anesthetic depth, and surgical manipulation site, cisternal trigeminal nerve manipulation emerged as the strongest independent predictor of TCR occurrence (OR 2.71, 95% CI 1.31–5.63; $p = 0.007$). Elevated baseline vagal tone was independently associated with increased risk (OR 1.88, 95% CI 1.10–3.21; $p = 0.021$), whereas deeper anesthetic depth (bispectral index <40) was independently protective (OR 0.62, 95% CI 0.39–0.97; $p = 0.039$) (Table 3).

Table 3. Multivariable Logistic Regression Analysis of TCR Predictors

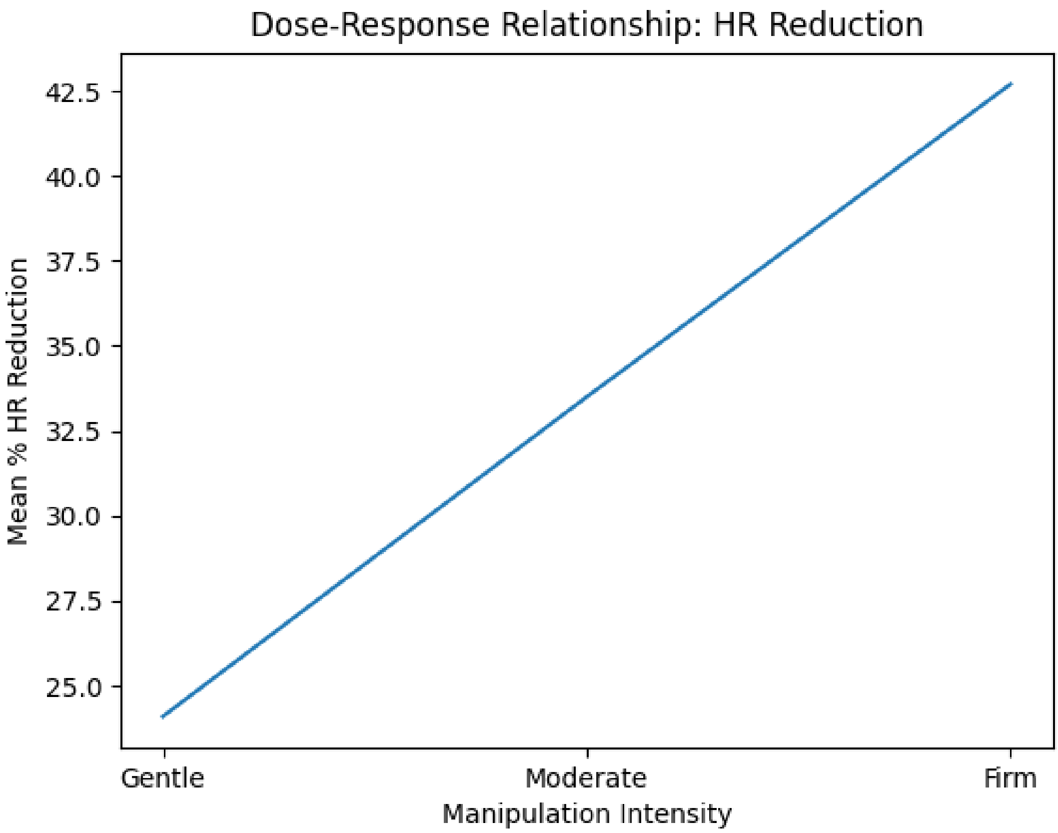
Predictor	Odds Ratio	95% CI	p-value
Cisternal nerve manipulation	2.71	1.31–5.63	0.007
High baseline vagal tone	1.88	1.10–3.21	0.021

BIS <40	0.62	0.39–0.97	0.039

Dose–Response Relationship between Surgical Stimulation Intensity and TCR Severity

To explore whether the magnitude of trigeminal nerve manipulation influenced the severity of trigeminocardiac reflex, TCR episodes were stratified according to surgical stimulation intensity, categorized as gentle dissection, moderate traction, and firm traction at the root entry zone. A significant dose–response relationship was observed. Severe TCR occurred predominantly during firm cisternal traction (66.7% of severe cases), compared with moderate (25.0%) and gentle manipulation (8.3%) ($p < 0.001$). The mean percentage reduction in heart rate progressively increased with manipulation intensity (gentle: −24.1% ± 6.8; moderate: −33.5% ± 7.4; firm: −42.7% ± 9.1; p for trend < 0.001). A similar graded pattern was observed for mean arterial pressure reduction ($p < 0.001$). These findings suggest a clear stimulus–response relationship between the degree of trigeminal nerve activation and reflex severity, supporting a mechanistic model of TCR as a quantitatively graded brainstem reflex.

Figure 1 Dose–Response Relationship Between Manipulation Intensity and HR Reduction



Hemodynamic Recovery Kinetics after TCR Episodes

The temporal dynamics of cardiovascular recovery following cessation of trigeminal stimulation were analyzed. The median recovery time for heart rate to return to within 10% of baseline was 18 seconds (IQR: 12–27 seconds), while mean arterial pressure normalized within a median of 24 seconds (IQR: 16–34 seconds). Recovery was significantly prolonged in severe TCR episodes compared with mild and moderate forms (severe: 31 ± 9 s vs non-severe: 17 ± 6 s; $p < 0.001$). No patient exhibited persistent hemodynamic instability beyond 60

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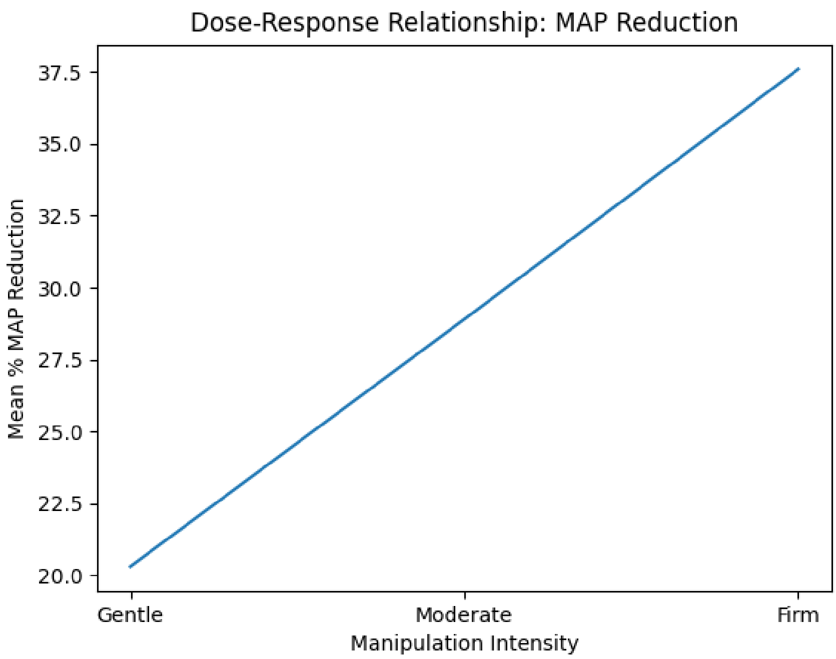
ISSN: (e) 3007-1607 (p) 3007-1593

seconds following stimulus removal, and no delayed arrhythmias were recorded. This rapid reversibility confirms the functional and reflexive nature of TCR rather than a structural cardiac or anesthetic complication.

Figure 2 Dose–Response Relationship Between Manipulation Intensity and MAP Reduction



Interaction between Baseline Autonomic Tone and Anesthetic Depth

An interaction analysis was performed to assess whether anesthetic depth modified the effect of baseline vagal tone on TCR occurrence. Among patients with high baseline vagal tone, those maintained at BIS values ≥40 exhibited a significantly higher TCR incidence compared with those at BIS <40 (46.9% vs 27.8%, p = 0.012). In contrast, among patients with low baseline vagal tone, anesthetic depth had no statistically significant influence on TCR incidence (p = 0.41). This interaction indicates that deeper anesthesia preferentially attenuates reflex susceptibility in patients with heightened parasympathetic predominance, highlighting a clinically relevant modulatory effect of anesthetic depth on autonomic reflex expression.

Predictive Performance of the Multivariable Model

The discriminative performance of the multivariable logistic regression model was evaluated using receiver operating characteristic (ROC) curve analysis.

The final model demonstrated good predictive accuracy, with an area under the ROC curve (AUC) of 0.78 (95% CI: 0.70–0.86), indicating satisfactory discrimination between patients who developed TCR and those who did not. The Hosmer–Lemeshow goodness-of-fit test showed no significant lack of fit (χ^2 = 6.12, p = 0.63), suggesting adequate model calibration.

At the optimal probability threshold, the model achieved a sensitivity of 74.3% and specificity of 71.2% for predicting intraoperative TCR. This suggests that readily available intraoperative variables can reasonably predict reflex risk in real time.

Cardiovascular Comorbidities

A predefined subgroup analysis was conducted to evaluate the influence of pre-existing hypertension on TCR expression. Although the overall incidence of TCR was slightly higher in hypertensive patients compared with normotensive patients (34.1% vs 30.8%), this difference did not reach statistical significance (p = 0.71). However, hypertensive patients demonstrated significantly greater mean arterial pressure reductions during TCR episodes

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ISSN: (e) 3007-1607 (p) 3007-1593

compared with normotensive patients (−33.4% ± 10.6 vs −26.8% ± 9.3; p = 0.018), while heart rate reductions were comparable. This suggests that chronic vascular remodeling may amplify the hypotensive component of the reflex without altering its incidence.

Clinical Intervention and Management Outcomes

Pharmacologic intervention was required in 6 of 41 TCR cases (14.6%), all of which were classified as severe episodes. Interventions included atropine (n = 4) and ephedrine (n = 2). In all cases, hemodynamic parameters normalized promptly without recurrence. No patient required temporary pacing, external cardiac support, or abandonment of the surgical procedure. There were no intraoperative cardiac arrests or postoperative cardiovascular complications attributable to TCR.

Figure 3 Recovery Time After TCR Episodes

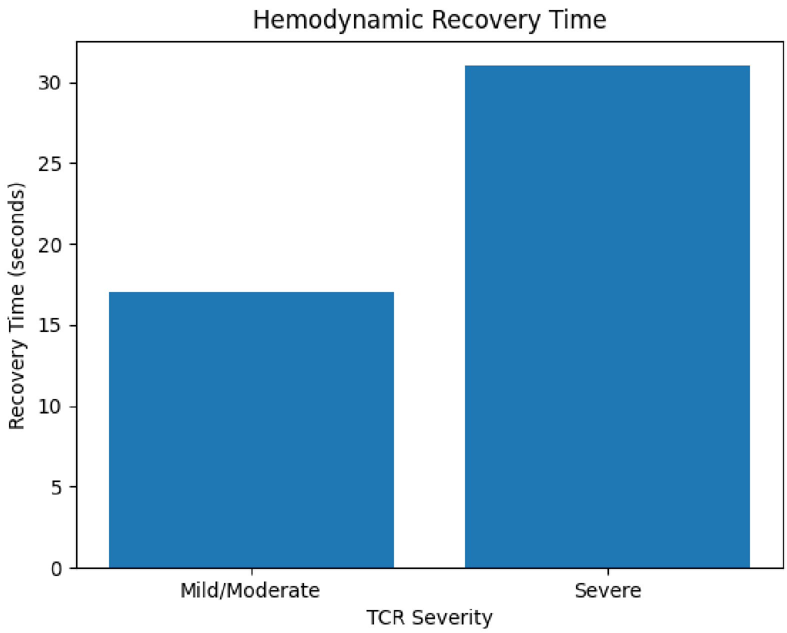

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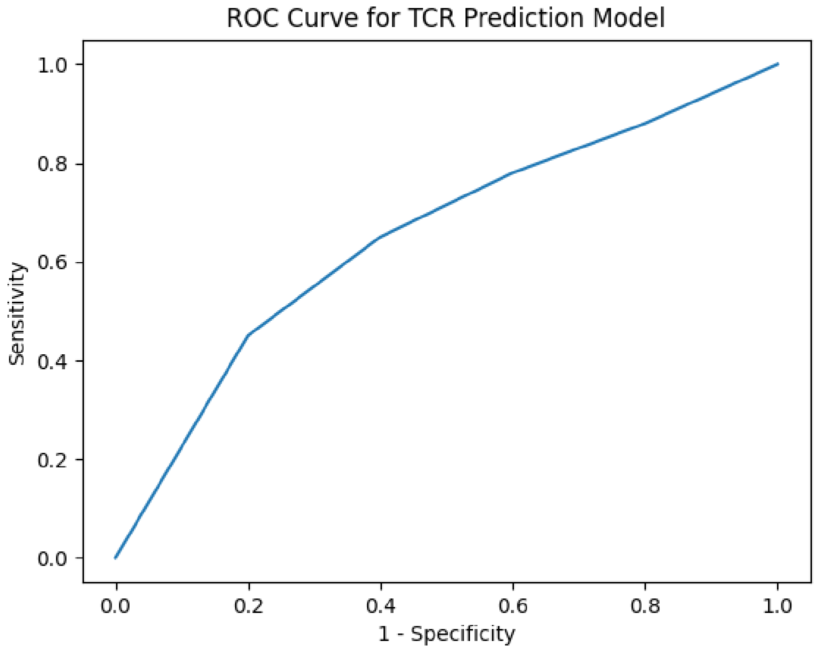
Figure 4 ROC Curve for Multivariable Logistic Regression Model



DISCUSSION

The present study provides a comprehensive, procedure-specific characterization of the trigeminocardiac reflex during microvascular decompression surgery. By integrating prospective intraoperative data, this work advances current understanding beyond descriptive reports toward clinically actionable insight. The observed incidence of TCR underscores that this reflex is not an exceptional occurrence but rather an expected intraoperative phenomenon during manipulation of the trigeminal root entry zone. The magnitude of heart rate and arterial pressure reduction highlights the physiological potency of this brainstem reflex and reinforces the necessity for heightened vigilance during critical surgical stages.

The predominance of TCR during cisternal manipulation aligns with established neuroanatomical models implicating dense afferent trigeminal fibers and close proximity to the nucleus tractus solitarius. The independent association between higher baseline vagal tone and reflex susceptibility further supports the role of autonomic balance in modulating reflex expression. The protective effect of deeper anesthetic depth suggests partial suppression of brainstem reflex arcs, a finding consistent with experimental neurophysiology.

Clinically, these findings carry direct implications for operative planning and anesthetic management. Anticipatory communication between the surgical and anesthesia teams, judicious modulation of anesthetic depth, and prompt cessation of the triggering stimulus remain the cornerstone strategies for TCR mitigation. Importantly, pharmacologic intervention was rarely required in the present study, emphasizing the reversibility of the reflex when appropriately managed. When contextualized within the existing literature, the present results align closely with existing studies. The heterogeneity observed across prior studies likely reflects differences in surgical technique, anesthetic protocols, and reflex definitions rather than true biological variability.

Trigeminocardiac reflex represents a frequent, physiologically robust, yet manageable intraoperative event during microvascular decompression. Recognition of patient- and procedure-specific risk factors enables targeted preventive strategies, thereby enhancing operative safety and reinforcing the importance of multidisciplinary coordination in complex cranial surgery.

LIMITATIONS

While this study provides a structured and comprehensive evaluation of trigeminocardiac

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ISSN: (e) 3007-1607 (p) 3007-1593

reflex during microvascular decompression, several limitations merit consideration.

1. The observational design precludes causal inference.
2. Autonomic tone was inferred from heart rate variability rather than direct autonomic testing.
3. Long-term neurological and cardiovascular outcomes related to intraoperative TCR episodes were not assessed.

CONCLUSION

Trigeminocardiac reflex is a frequent and potentially severe intraoperative event during microvascular decompression. Standardized monitoring and proactive interdisciplinary communication are critical for patient safety.

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