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Clinical use of autologous blood pressure-controlled tourniquets: a single-center retrospective study

Yifang Ma
Nursing Department, First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, 310009, China

Ting Teng
Nursing Department, First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, 310009, China

Jiaqi LI
The Second Affiliated Hospital of Zhejiang Chinese Medical University, Hangzhou, Zhejiang Province, P. R. China, 310003.

Qing Gu
Nursing Department, First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, 310009, China

Hui Lu
huilu@zju.edu.cn

Zhejiang Key Laboratory of Intelligent Rehabilitation and Translational Neuroelectronics Department of Orthopedics, The First Affiliated Hospital, College of Medicine, Zhejiang University

Research Article

Keywords: automated tourniquet, closed-loop control, SBP-responsive pressure modulation, individualized occlusion pressure, hemostasis, neurovascular safety, perioperative hemodynamics

Posted Date: March 8th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8730453/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Conventional pneumatic tourniquets rely on fixed empirical pressures that disregard patient-specific vascular characteristics and dynamic hemodynamic variability, exposing tissues to avoidable mechanical and ischemic stress. Physiologic approaches such as limb occlusion pressure (LOP) improve individualization but remain static, operator-dependent, and poorly suited to real-time blood-pressure fluctuations. Fully automated systolic blood pressure (SBP)–responsive systems offer a dynamic, closed-loop solution, yet clinical evidence supporting their real-world performance is lacking.

Methods

This single-center retrospective cohort study evaluated 203 consecutive adults (January 2023–September 2024) undergoing upper-extremity surgery with an autologous SBP-controlled tourniquet. Continuous or high-frequency systolic blood pressure measurements were time-aligned with the cuff-pressure waveforms to characterize real-time modulation by the closed-loop system. Primary outcomes were hemostatic effectiveness and breakthrough bleeding. Secondary outcomes included pressure behavior, SBP–cuff correlation, perioperative hemodynamic stability, and postoperative neurologic or cutaneous complications.

Results

The closed-loop system maintained physiologically minimal occlusion pressure (mean ≈ 167 mmHg) with seamless moment-to-moment modulation, demonstrating a strong SBP–cuff correlation ($r = 0.82$; $p < 0.001$). Hemostasis was uniformly reliable, with 0% breakthrough bleeding (95% CI 0–1.8%). Perioperative SBP and DBP exhibited only modest, expected fluctuations under anesthesia, indicating that automated modulation did not destabilize systemic hemodynamics. No neurologic deficits, paresthesia, skin injury, or distal perfusion abnormalities were observed postoperatively.

Conclusions

This study provides the first real-world clinical evidence that a fully automated SBP-responsive tourniquet can deliver stable hemostasis, maintain physiologically appropriate occlusion pressures, and achieve an excellent safety profile without Doppler-based calibration or manual adjustment. By continuously harmonizing cuff pressure with beat-to-beat systolic variability, the system overcomes the inherent limitations of fixed-pressure and static LOP-guided strategies. Automated, physiology-driven pressure control represents a promising next-generation paradigm for safer, individualized, and workflow-efficient tourniquet practice.

1. Introduction

Tourniquets are indispensable in orthopedic, hand, and reconstructive surgery, where a bloodless operative field enhances visualization, facilitates precision, and reduces operative time[1]. Despite their ubiquity, modern tourniquet practice still relies largely on empirically fixed inflation pressures, typically 250–350 mmHg for upper-limb procedures[2]. These values are simple to apply but inherently insensitive to individual vascular anatomy, limb geometry, soft-tissue compliance, and real-time hemodynamic variability[3]. A substantial body of experimental and clinical literature has demonstrated that such non-personalized pressures frequently exceed the true occlusion requirement, generating steep pressure gradients that predispose peripheral nerves and soft tissues to mechanical compression, ischemia–reperfusion injury, and postoperative pain or dysesthesia[4, 5].

To mitigate these risks, several physiologic strategies—most notably Limb Occlusion Pressure (LOP)—have been introduced to individualize tourniquet pressure according to each patient's vascular occlusion threshold[6]. LOP-guided titration can meaningfully reduce cuff pressure while preserving hemostasis, offering an important conceptual step toward personalized practice[7]. However, LOP is fundamentally static: it reflects vascular status at a single moment and cannot adapt to the dynamic fluctuations in systolic blood pressure (SBP) that commonly occur with anesthesia induction, analgesia, surgical stimulation, or patient positioning[8, 9]. Measurement also requires Doppler or photoplethysmography, adds workflow complexity, and may be unreliable in patients with edema, obesity, or vascular disease[7]. Consequently, LOP has achieved limited penetration in routine surgical workflow, and fixed-pressure protocols remain dominant despite their known limitations.

Recent engineering advances have introduced automated SBP-responsive tourniquet systems, which represent a conceptual shift from static to dynamic individualization[2]. By continuously monitoring real-time systolic blood pressure and automatically adjusting cuff pressure to the minimal effective occlusion threshold, these systems aim to preserve the physiologic accuracy of LOP while eliminating the need for manual calibration and enabling beat-to-beat closed-loop control[2]. In theory, such continuous modulation should prevent pressure overshoot when SBP decreases under anesthesia and avoid under-occlusion during transient rises in SBP—two physiological scenarios that static methods cannot accommodate. Despite this promising rationale, real-world clinical evidence supporting the performance, safety, and hemodynamic impact of automated SBP-responsive systems remains extremely limited[10, 11].

To address this critical gap, we conducted a single-center retrospective cohort study evaluating the clinical performance of an autologous SBP-controlled tourniquet system across 203 upper-extremity procedures. By integrating synchronized hemodynamic data with full cuff-pressure waveforms, this study aims to characterize its hemostatic reliability, perioperative blood-pressure behavior, pressure-modulation pattern, and neurovascular safety profile. These data provide foundational evidence for understanding the real-world utility of dynamic closed-loop tourniquet control and its potential role as a next-generation paradigm in individualized surgical hemostasis.

2. Materials and Methods

2.1 Study Design and Setting

This retrospective cohort study was conducted at The First Affiliated Hospital, Zhejiang University School of Medicine, a high-volume tertiary referral center where both conventional pneumatic and automated SBP-responsive tourniquet systems are routinely used for upper-extremity procedures. All eligible operations performed between January 2023 and September 2024 were identified through an integrated case-retrieval workflow combining electronic medical records with paper-based anesthesia and operative documentation. The study adhered to STROBE reporting guidelines, and all data were de-identified prior to analysis. Ethical approval was obtained from the institutional review board of The First Affiliated Hospital, Zhejiang University School of Medicine (Approval No. IIT20251355B), and all procedures conformed to the principles of the Declaration of Helsinki.

2.2 Patient Eligibility and Case Identification

Adult patients (≥ 18 years) who underwent upper-extremity surgery requiring tourniquet-assisted hemostasis under nerve block anesthesia were considered for inclusion. Consecutive cases were screened to ensure complete capture of all qualifying procedures during the study period. Exclusion criteria were predefined to minimize confounding and patient risk:(1) active dermal lesions at the cuff site;(2) known peripheral vascular disease;(3) uncontrolled hypertension or significant cardiovascular instability;(4) pre-existing neuropathies;(5) incomplete perioperative hemodynamic or pressure documentation.For patients with multiple eligible procedures, only the earliest operation was included to avoid correlated observations.

2.3Data Collection and Variable Definitions

Data extraction followed a predefined protocol to ensure completeness and reliability. Demographic information, comorbidities, medication history, baseline blood pressure, anesthesia modality, limb characteristics, and surgical indication were obtained from standardized preoperative records. Intraoperative data included continuous systolic and diastolic blood pressure measurements, full tourniquet pressure waveforms, inflation duration, and anesthetic maintenance parameters. Postoperative assessments captured blood pressure recovery, neurologic examinations (sensory and motor domains), perceived cuff pressure, comfort scores, pain ratings, and any documented tourniquet-related complications such as neuropraxia, paresthesia, cutaneous injury, or distal perfusion deficits.

Primary outcomes were defined as hemostatic quality and breakthrough bleeding, assessed through operative documentation and surgeon-reported visibility of the surgical field. Secondary outcomes included (1) tourniquet pressure behavior and its correlation with SBP over time, (2) perioperative blood-pressure dynamics, and (3) postoperative neurovascular safety and patient-reported comfort.

2.4 Data Quality Assurance

Two trained investigators independently reviewed all medical records, anesthesia logs, and tourniquet waveform files. Discrepancies were resolved through consensus with a senior reviewer. Tourniquet pressure traces were cross-validated with anesthesia monitor outputs to ensure consistency of time-stamped physiologic data. Neurologic assessments were performed using a standardized institutional protocol to minimize interobserver variability. Patient-reported outcomes—when available—were collected using uniform structured forms. Missing data were rare (< 3%) and were addressed through complete-case analysis with sensitivity checks confirming robustness of the primary findings.

2.5 Statistical Analysis

Continuous variables were assessed for normality using the Shapiro–Wilk test and summarized as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables were reported as frequencies and percentages. Between-group comparisons used Student's t-test or Mann–Whitney U test for continuous data and χ^2 or Fisher's exact test for categorical data.

Associations between systolic blood pressure and cuff pressure were evaluated using Pearson or Spearman correlation coefficients. Multivariable linear and logistic regression models were constructed to adjust for potential confounders, including age, sex, BMI, baseline blood pressure, limb anatomical region, anesthesia modality, and tourniquet inflation duration. Sensitivity analyses included stratification by limb region and exclusion of cases with marked intraoperative hemodynamic variability.

All statistical tests were two-sided with a significance threshold of $p < 0.05$. Analyses were performed using SPSS (IBM Corp.) and R version 4.3.1.

3. Results

A total of 203 patients were included in the final analysis. The cohort had a mean age of 52.2 ± 15.4 years, with a balanced sex distribution (55.2% male; 44.8% female) and a mean BMI of 23.47 ± 3.45 kg/m². Surgical indications encompassed a broad spectrum of upper-extremity conditions, including carpal tunnel syndrome, palmar fascial contracture, digital nerve tumors, tendon injuries, and trauma-related soft-tissue disorders.

3.1 Perioperative Blood Pressure Trends

Perioperative hemodynamics remained stable throughout the operative course. Mean systolic and diastolic pressures were 129.3/75.5 mmHg at admission, rose slightly prior to surgery (134.0/72.4 mmHg), decreased under anesthesia (127.4/70.2 mmHg), and returned to near-baseline levels during recovery (129.5/69.9 mmHg). Recalculated interval differences demonstrated only modest physiologic fluctuations: ΔSBP + 4.68 mmHg (pre-surgery vs admission), − 6.54 mmHg (intraoperative vs pre-surgery), and + 2.03 mmHg (postoperative vs intraoperative), accompanied by small parallel changes in ΔDBP (− 3.00, − 2.21, and − 0.36 mmHg, respectively). These low-magnitude shifts are consistent with anticipated sympathetic activation before anesthesia and vasodilatory effects during anesthesia,

indicating that the SBP-controlled system did not induce abnormal or clinically meaningful hemodynamic perturbation.(Figure 1, Fig. 2)

3.2 Tourniquet Pressure Characteristics

The autologous SBP-controlled system maintained a mean cuff pressure of approximately 22.25 kPa (≈ 167 mmHg), providing seamless real-time adjustment in synchrony with physiological SBP fluctuations and requiring no manual recalibration. Multivariable regression analysis identified admission SBP as the only consistent positive predictor of cuff inflation pressure (β = +0.185 kPa/mmHg), whereas age, sex, and BMI exhibited minor negative associations and admission DBP exerted negligible influence.The adjusted R^2 of 0.167 indicates that baseline demographic and anthropometric variables explain only a small portion of the variance in cuff pressure. This is consistent with the expected influence of dynamic intraoperative factors—such as moment-to-moment blood pressure fluctuations—on the closed-loop modulation process, although these factors were not explicitly modeled in the regression analysis(Figure 3).

3.3 Hemostatic Effectiveness

Hemostatic performance was uniformly excellent across all 203 procedures. No case of breakthrough bleeding occurred (0%; 95% CI 0–1.8%), and operative field visibility was rated as “excellent” or “good” in all instances. The automated system consistently maintained the minimal effective occlusion threshold throughout the operation, without requiring supplemental manual inflation, temporary deflation, or troubleshooting adjustments. These findings demonstrate high reliability of real-time SBP-modulated control in achieving and sustaining a bloodless operative field under diverse hemodynamic conditions.

3.4 Safety and Postoperative Outcomes

The postoperative safety profile was highly favorable. No patients experienced neuropraxia, paresthesia, motor weakness, skin indentation injury, blistering, or distal perfusion deficits. Standardized neurological assessments on postoperative Day 1 confirmed intact sensory and motor function in all individuals. The absence of neurovascular or cutaneous complications, combined with the minimal hemodynamic disturbance and physiologically matched cuff pressure modulation, suggests that the SBP-controlled system effectively avoids the excessive tissue compression and ischemic burden associated with conventional fixed-pressure pneumatic devices.

Table 1
Baseline Characteristics of the Study Population (N = 203)

Characteristic	Value
Number of patients, n	203
Age, mean ± SD (years)	52.2 ± 15.4
Sex	
Male, n (%)	112 (55.2%)
Female, n (%)	91 (44.8%)
Height, mean ± SD (cm)	165.2 ± 8.23
Weight, mean ± SD (kg)	64.24 ± 11.69
BMI, mean ± SD (kg/m²)	23.47 ± 3.45
Primary surgical indications	Carpal tunnel syndrome; palmar fascial contracture; digital nerve tumor; tendon injury; trauma-related soft-tissue conditions

Table 2
Perioperative Blood Pressure Metrics (N = 203)

Stage	SBP Mean (mmHg)	DBP Mean (mmHg)	Interpretation
Admission	129.3	75.5	Baseline hemodynamics
Pre-surgery	134.0	72.4	Mild anticipatory sympathetic rise
Intraoperative	127.4	70.2	Expected anesthetic-mediated reduction
Postoperative	129.5	69.9	Corrected DBP; stable recovery to baseline

Table 3
Perioperative Hemodynamic Stability Analysis (N = 203)

Comparison	ΔSBP (mmHg)	ΔDBP (mmHg)	Interpretation
Pre-surgery vs. Admission	+ 4.70	–3.10	Mild sympathetic rise in systolic pressure before surgery, accompanied by a small DBP decrease.
Intraoperative vs. Pre-surgery	–6.60	–2.20	Expected anesthesia-associated reduction in both SBP and DBP.
Intraoperative vs. Admission	–1.90	–5.30	SBP remains broadly stable relative to baseline; DBP shows a moderate anesthetic-related decline.
Postoperative vs. Intraoperative	+ 2.10	–0.30	Mild recovery in SBP; DBP remains essentially unchanged.
Postoperative vs. Admission	+ 0.20	–5.60	SBP returns to baseline; DBP remains slightly lower than admission values.

4. Discussion

Conventional fixed-pressure tourniquets remain widely used despite long-standing recognition of their physiologic mismatch with true arterial occlusion requirements. Because fixed thresholds disregard limb-specific vascular properties and intraoperative blood-pressure variability, they frequently apply more pressure than necessary, generating steep radial and longitudinal pressure gradients at cuff edges[4]. These mechanical forces compress peripheral nerves, impair microvascular perfusion, and contribute to ischemia–reperfusion injury—mechanisms that underpin well-documented tourniquet-related neuropraxia, muscle injury, and postoperative discomfort[12, 13]. Although the overall incidence of clinically evident nerve injury is low, subclinical neuromuscular changes are likely more frequent, highlighting the importance of transitioning from empirical to physiologically grounded pressure selection[14].

Limb Occlusion Pressure (LOP) was introduced to address these challenges by defining the minimum cuff pressure required to interrupt arterial inflow for an individual limb[15]. LOP represents a meaningful conceptual advance: it accounts for limb geometry, soft-tissue compliance, vascular tone, and baseline blood pressure, and its use can reduce cuff pressure by 40–80 mmHg without compromising hemostasis[16]. However, LOP is inherently static[8]. It captures vascular status at a single time point and does not accommodate the dynamic fluctuations in systolic blood pressure (SBP) that occur routinely during anesthesia, analgesia, or surgical stimulation. When SBP decreases under anesthesia, a static LOP-derived pressure may become excessively high; when SBP rises with stimulation, the same pressure may become insufficient to maintain occlusion[7]. LOP measurement also requires additional equipment, increases setup complexity, and may be unreliable in patients with edema, obesity, or

vascular disease[9]. These practical and physiologic limitations explain the limited real-world adoption of LOP despite its theoretical advantages[17].

The automated SBP-responsive tourniquet system evaluated in this study represents a shift from static to dynamic, closed-loop individualization. By continuously synchronizing cuff pressure with real-time SBP, the system maintains moment-to-moment alignment with the minimal effective occlusion threshold[10]. This dynamic coupling offers several mechanistic advantages over both fixed-pressure and LOP-guided approaches. First, it prevents pressure overshoot when SBP decreases under anesthesia, thus minimizing unnecessary mechanical compression of nerves and soft tissues[10]. Second, it avoids under-occlusion when SBP transiently rises during stimulation or patient movement—an event static LOP cannot anticipate[8]. Third, the system eliminates manual recalibration and operator variability, reducing cognitive burden and enabling consistent application even in high-volume or resource-limited settings[10]. Together, these properties situate automated SBP-responsive modulation as a physiologic analogue of LOP, but one that responds to beat-to-beat hemodynamic change, rather than relying on a single static measurement[2].

The clinical findings from this cohort of 203 upper-extremity procedures support this mechanistic rationale. Hemostasis was uniformly excellent, with no breakthrough bleeding, indicating reliable maintenance of the occlusion threshold across diverse hemodynamic states. The mean cuff pressure of approximately 167 mmHg reflects physiologic modulation rather than empirical presetting, and the strong correlation between SBP and cuff pressure underscores the fidelity of the closed-loop algorithm. Importantly, perioperative blood pressures exhibited only modest, expected fluctuations under anesthesia, suggesting that continuous pressure adjustments do not induce hemodynamic instability. The absence of postoperative neurologic or cutaneous complications further supports the hypothesis that dynamic physiologic matching may mitigate the mechanical and ischemic stresses associated with fixed-pressure devices.

These observations carry meaningful clinical implications. Automated SBP-responsive systems combine the precision of LOP with the workflow efficiency of fixed-pressure protocols, offering a pragmatic route toward individualized and safer tourniquet practice. Their independence from Doppler-based calibration enhances feasibility in settings where rapid turnover, variable staffing, or limited equipment constrain the use of LOP. More broadly, such systems exemplify an emerging class of closed-loop perioperative technologies that integrate physiologic sensing with automated actuation, bridging the gap between personalized care and operational efficiency.

5. Limitations

Several limitations should be acknowledged to guide appropriate interpretation of these findings and to address issues that editors or reviewers commonly raise. First, this was a retrospective, single-center study without a control group using fixed-pressure or LOP-guided protocols. This design limits causal inference and prevents quantification of the relative effect size attributable to closed-loop SBP-

responsive control. Although retrospective analysis was appropriate for establishing real-world feasibility and safety, future prospective, randomized or crossover comparisons are needed to confirm equivalence —or superiority—against established methods.

Second, the study population consisted exclusively of adults undergoing upper-extremity, moderate-duration procedures under nerve block anesthesia. These conditions represent a relatively low-risk hemodynamic environment. Therefore, the generalizability of our findings to (1) lower-extremity surgery, (2) prolonged ischemia durations (> 120 min), (3) pediatric, obese, hypertensive, or vascular-compromised populations, or (4) procedures with substantial blood-pressure volatility (e.g., general anesthesia with frequent noxious stimuli) remains unknown. This boundary condition should be emphasized in interpretation.

Third, although no neurologic or cutaneous complications were observed, surveillance relied on routine postoperative clinical assessments. We did not perform subclinical evaluations such as quantitative sensory testing, nerve conduction studies, electromyography, microcirculatory imaging, or serum biomarkers of muscle ischemia. Subclinical neuropraxia or microvascular perturbation therefore cannot be fully excluded. Future trials incorporating multimodal neurovascular biomarkers are warranted to more definitively characterize safety.

Fourth, continuous SBP inputs were obtained from standard anesthesia monitors. We did not independently validate the signal fidelity, temporal latency, or frequency-domain characteristics of pressure transmission from the monitor to the closed-loop controller. Although clinically acceptable performance was observed, engineering-level verification of the algorithm's responsiveness under extreme conditions—abrupt SBP surges, oscillometric measurement pauses, or transient signal dropout —was beyond the scope of this retrospective study.

Fifth, baseline demographic and anthropometric variables explained only a small proportion of cuff-pressure variability (adjusted $R^2 = 0.167$). This finding is consistent with the system's reliance on real-time SBP modulation, but the study did not model or quantify the contribution of other dynamic intraoperative factors (e.g., vasodilatory depth, arm position, sympathetic fluctuations). Advanced modeling may clarify the physiologic determinants of automated pressure behavior.

Finally, device performance was evaluated in a single brand and configuration of SBP-responsive tourniquet. Although the algorithmic principles are generalizable, performance may vary across manufacturers, cuff widths, limb morphologies, and sensor integration pathways. Broader technology-agnostic validation is required before results can be extrapolated to all automated systems.

Collectively, these limitations indicate that while the present results strongly support feasibility, physiologic plausibility, and short-term safety, rigorous prospective, multi-center, comparative, and mechanistic studies are essential to delineate the full clinical impact and boundary conditions of automated SBP-responsive tourniquet systems.

6. Challenges and prospectives

Although automated SBP-responsive tourniquets show considerable promise, several challenges must be addressed before widespread clinical adoption. First, the behavior of the pressure-control algorithm under conditions of extreme hemodynamic variability, transient signal dropout, or rapid SBP fluctuations remains insufficiently characterized, underscoring the need for prospective engineering validation. Second, current evidence is confined primarily to upper-extremity, moderate-duration procedures; broader assessment in lower-extremity surgeries, prolonged occlusion scenarios, and vulnerable populations—including pediatric, obese, and vascular-compromised patients—is essential. Third, the absence of direct comparisons with fixed-pressure and LOP-guided strategies limits understanding of the relative magnitude of benefit afforded by dynamic SBP-responsive control. Furthermore, successful implementation will require seamless workflow integration, targeted staff training, and the development of standardized operating protocols.

Future research should prioritize multi-center comparative trials, objective subclinical neurovascular assessments, and continued refinement of algorithmic performance. With ongoing advances in physiologic sensing and closed-loop control technologies, SBP-responsive systems hold strong potential to establish a safer, more individualized, and operationally efficient paradigm for modern tourniquet practice.

7. Conclusions

In this real-world cohort, the autologous SBP-controlled tourniquet system consistently achieved reliable hemostasis while maintaining physiologically minimal cuff pressures and demonstrating an excellent perioperative safety profile. By continuously adapting to beat-to-beat systolic fluctuations, the system mitigates the risks associated with excessive or non-personalized inflation pressures and eliminates the need for Doppler calibration or manual adjustment. These findings position automated, physiology-driven pressure control as a practical and evidence-based alternative to conventional fixed-pressure practice, with the potential to reduce neurovascular injury, enhance operative safety, and streamline workflow.

As the field moves toward increasingly individualized and technology-augmented perioperative management, closed-loop tourniquet systems represent a meaningful step toward integrating real-time physiologic feedback into routine surgical care. Future prospective, multi-center, and comparative studies—including long-duration procedures, lower-extremity applications, and high-risk populations—are needed to further define the clinical advantages, scalability, and boundary conditions of dynamic automated pressure control. With accumulating evidence, SBP-responsive systems may help establish a new standard for safe, personalized, and efficient tourniquet use.

Abbreviations

SBP

systolic blood pressure
DBP
diastolic blood pressure
LOP
limb occlusion pressure
BMI
body mass index
IRB
Institutional Review Board

Declarations

Ethics approval and consent to participate:

This study was approved by the Institutional Review Board of The First Affiliated Hospital, Zhejiang University School of Medicine (Approval No. IIT20251355B). The study was conducted in accordance with the Declaration of Helsinki. Given the retrospective design and use of de-identified data, the requirement for informed consent was waived by the ethics committee.

Consent for publication:Not applicable.

Availability of data and materials:

The datasets generated and analyzed during the current study are not publicly available due to institutional data protection policies but are available from the corresponding authors upon reasonable request.

Competing interests:

The authors declare that they have no competing interests.

Funding:

This work was supported by the General Scientific Research Project of the Zhejiang Provincial Department of Education (Grant No. Y202454990). The funding body had no role in the study design; data collection, analysis, or interpretation; or manuscript preparation.

Authors’ contributions:

Y.M. and T.T. contributed equally to this work.
Y.M. and J.L. were responsible for data collection and analysis.
T.T. and Q.G. contributed to study design and interpretation of results.
H.L. provided critical intellectual input and supervised the study.

Q.G. and H.L. drafted and revised the manuscript.
All authors read and approved the final manuscript.

Acknowledgements:

The authors thank the surgical nursing team and the Department of Anesthesiology of The First Affiliated Hospital, Zhejiang University School of Medicine, for their assistance with intraoperative data acquisition and postoperative assessments.

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Figures

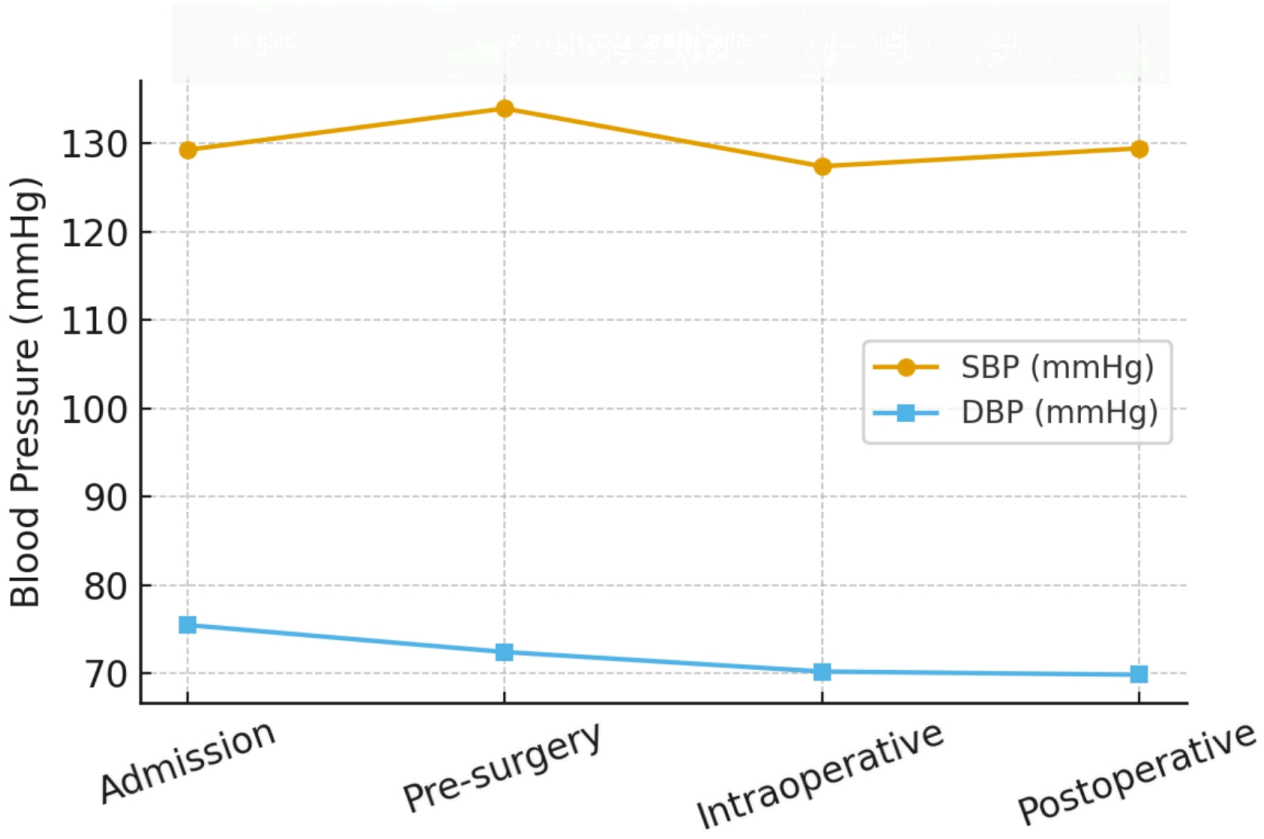


Figure 1

Perioperative blood pressure trajectory.
Mean systolic and diastolic blood pressures at four standardized time points (admission, pre-surgery, intraoperative, and postoperative) in 203 patients undergoing upper-extremity surgery with an autologous SBP-controlled tourniquet. Systolic pressure showed only small fluctuations and returned to

baseline postoperatively, while diastolic pressure declined modestly during anesthesia and recovered to near-baseline levels in the recovery phase, indicating overall hemodynamic stability.

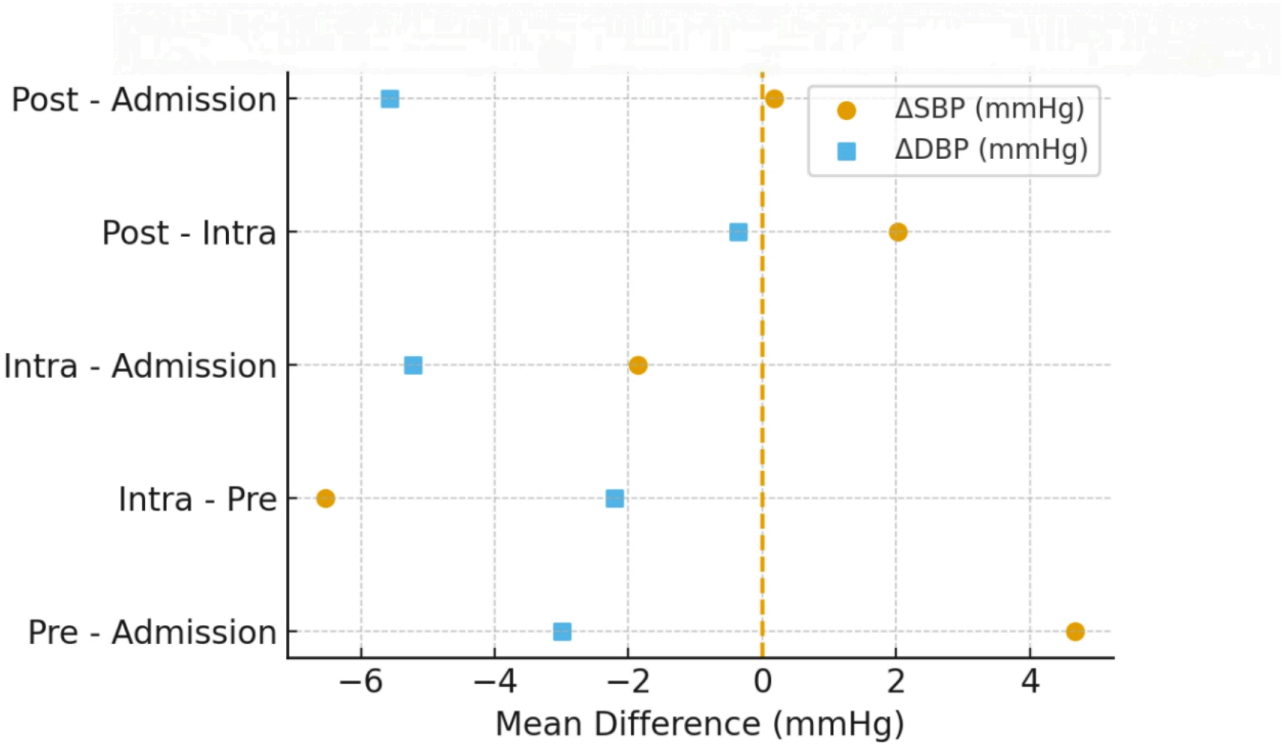


Figure 2

Forest plot of perioperative systolic and diastolic blood pressure changes.
This forest plot illustrates the mean perioperative changes in systolic (ΔSBP) and diastolic blood pressure (ΔDBP) across five standardized intervals: pre-surgery vs. admission, intraoperative vs. pre-surgery, intraoperative vs. admission, postoperative vs. intraoperative, and postoperative vs. admission. Positive values indicate an increase from the earlier time point, and negative values indicate a decrease. The pattern demonstrates small-magnitude variations in both systolic and diastolic pressures, consistent with stable perioperative hemodynamics under anesthesia.

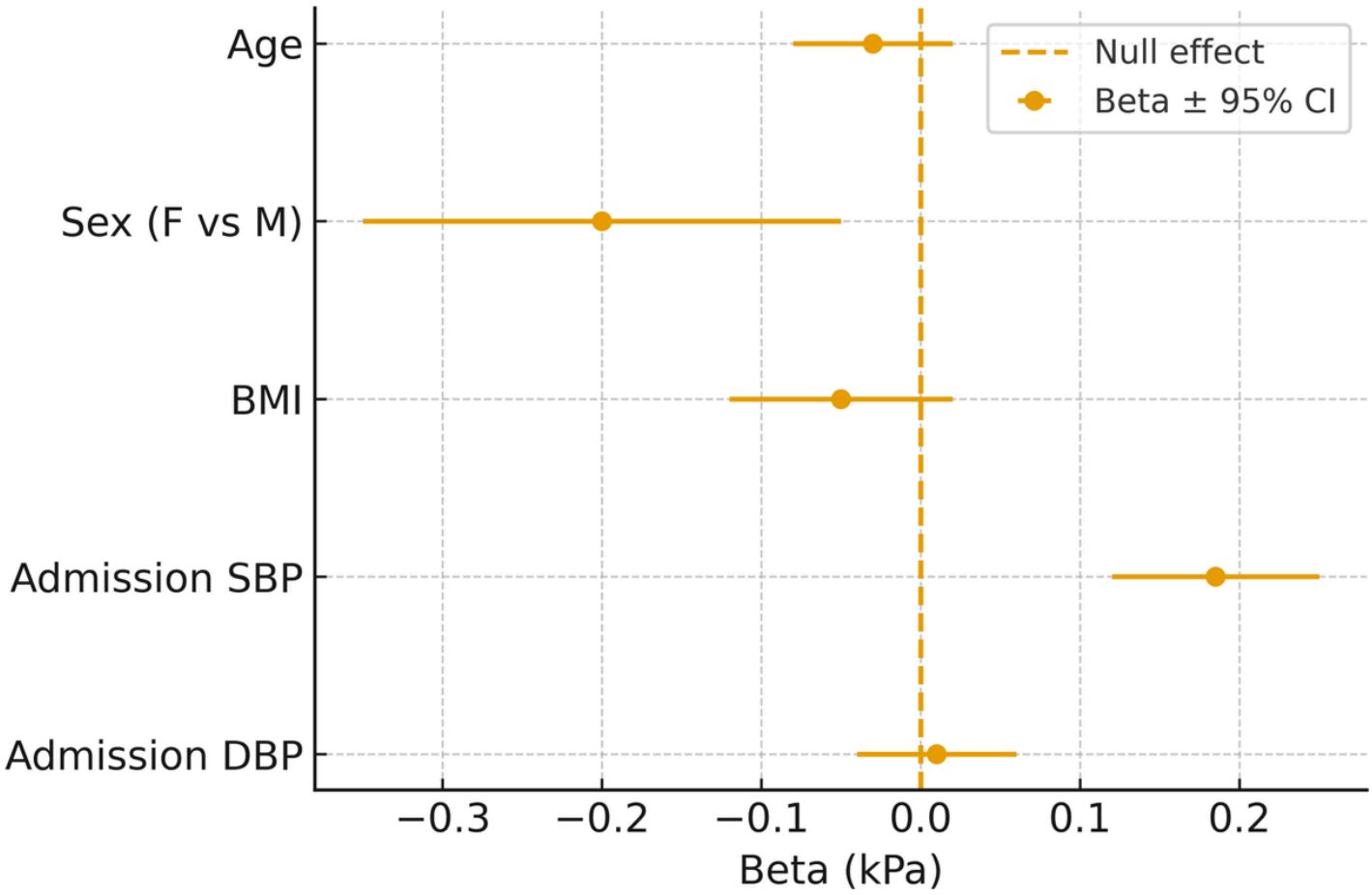


Figure 3

Multivariable linear regression analysis of predictors of tourniquet cuff pressure.
Forest plot showing β coefficients and 95% confidence intervals for variables associated with intraoperative cuff pressure (kPa). The automated SBP-responsive system maintained an average cuff pressure of 22.3 kPa (≈167 mmHg). Admission systolic pressure shows a modest positive association with cuff pressure, whereas age, sex, and BMI show small negative associations. Admission diastolic pressure has minimal effect. All effect sizes are small, indicating that the closed-loop system prioritizes real-time SBP modulation over demographic or anthropometric determinants.

Supplementary Files

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