Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/s3q0s297

COMPARISON OF EFFECTS OF TRENDELENBURG 20 DEGREE, PASSIVE LEG RAISING AT 45 DEGREES AND SUPINE POSITION ON HEMODYNAMIC CHANGES AFTER TOURNIQUET DEFLATION IN ORTHOPEDIC LOWER LIMB SURGERY UNDER SPINAL ANESTHESIA, A PROSPECTIVE PARALLEL CONTROLLED STUDY

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Abstract

Background: Pneumatic tourniquets are frequently used in orthopedic lower limb surgeries to minimize intraoperative blood loss and enhance the surgical field. However, tourniquet deflation can lead to hemodynamic instability, including hypotension and tachycardia. Physical maneuvers such as the Trendelenburg and passive leg raising (PLR) positions have been used to counteract these changes, but their comparative efficacy remains underexplored.

Aim: To compare the effectiveness of the Trendelenburg position, passive leg raising, and supine positioning in attenuating hemodynamic disturbances following tourniquet deflation in patients undergoing lower limb surgery under spinal anesthesia.

Methods: A prospective, randomized study was conducted on 90 ASA I–II patients undergoing lower limb surgery under spinal anesthesia. Patients were divided into three groups of 30 each: Group T (Trendelenburg), Group P (PLR), and Group C (supine control). Hemodynamic parameters including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) were recorded at baseline, post-deflation, and at regular intervals for 15 minutes. Total intravenous fluid requirement and need for vasopressors were also noted.

Results: Trendelenburg positioning resulted in significantly better maintenance of SBP, MAP, and HR after tourniquet deflation compared to the PLR and supine groups ($p < 0.05$). Group T also required a significantly lower volume of crystalloids (1.9 ± 0.40 L) compared to Group P (2.33 ± 0.47 L) and Group C (2.14 ± 0.67 L) ($p = 0.007$). No patient in the Trendelenburg group required vasopressor support, whereas isolated cases in Groups P and C did. The incidence of complications was lower in Group T, although not statistically significant.

Conclusion: The Trendelenburg position is superior to passive leg raising and supine positioning in maintaining hemodynamic stability and reducing fluid requirement following tourniquet deflation in lower limb surgeries under spinal anesthesia. It is a simple and effective intervention that can be safely implemented in the operating room to prevent post-deflation hypotension.

Keywords: Tourniquet deflation, Trendelenburg position, Passive leg raising, Hemodynamic changes, Spinal anesthesia, Orthopedic surgery

Introduction

The pneumatic tourniquet is a commonly used device in orthopedic limb surgeries, primarily to reduce intraoperative bleeding, maintain a dry surgical field, and facilitate the identification of anatomical structures [1]. Initially developed by Harvey Cushing in 1904, the pneumatic tourniquet has since become a standard component in extremity surgeries, as well as in combat and civilian emergency settings [2].

Tourniquet application is associated with various hemodynamic and metabolic changes that depend on the inflation-deflation phases, duration of application, extent of ischemia, anesthetic technique employed (general, spinal, or epidural), and the patient's cardiovascular status [3]. The introduction of wide, electronically controlled pneumatic cuffs has contributed to improved safety; however, tissue compression and ischemia-reperfusion injuries remain significant concerns. These effects may contribute to extended hospitalization and delayed postoperative recovery when compared with non-tourniquet-assisted procedures [1].

Tourniquet deflation leads to sudden physiological changes, including a redistribution of blood volume toward the previously ischemic limb. This results in decreased cardiac preload and mean arterial pressure (MAP), primarily due to the release of accumulated metabolites and a subsequent reduction in peripheral vascular resistance [4]. Clinically, these changes manifest as hypotension, tachycardia, a transient increase in cardiac index, and alterations in metabolic parameters such as elevated $EtCO_2$, increased $PaCO_2$, decreased pH, and lactic acidosis [4].

While these alterations may be well tolerated in healthy individuals, they can pose serious risks in patients with comorbidities, particularly cardiovascular disease or advanced age. In extreme cases, severe hemodynamic fluctuations following tourniquet deflation have led to cardiac arrest [5]. To mitigate these complications, various strategies such as intravenous fluid administration and vasopressors have been used. Although effective, fluid resuscitation requires time and may increase preload if administered preemptively [1].

To address hypotension and hypovolemia more promptly, positional maneuvers such as the Trendelenburg position and Passive Leg Raising (PLR) are commonly used. These maneuvers temporarily increase venous return, thereby enhancing cardiac preload, tissue perfusion, and hemodynamic stability [1].

The Trendelenburg position, originally popularized by Friedrich Trendelenburg in the 19^{th} century to improve access to pelvic organs, involves elevating the pelvis above the horizontal plane in a supine patient. It has been utilized for improving venous return, increasing vein size during catheterization, and reducing the risk of air embolism [6,7]. However, some studies have suggested that this position may impair gas exchange and cardiac function [8].

Passive Leg Raising, by elevating the lower extremities to approximately 45 degrees, serves as a reversible autotransfusion technique, increasing preload and stabilizing blood pressure following tourniquet deflation [5].

In this prospective controlled study, we aim to compare the effects of Trendelenburg position at 20 degrees, PLR at 45 degrees, and the standard supine position on hemodynamic changes following tourniquet deflation during orthopedic lower limb surgeries conducted under spinal anesthesia.

Aim

To compare the effects of Trendelenburg position at 20 degrees, passive leg raising (PLR) at 45 degrees, and the supine position on hemodynamic changes following tourniquet deflation in patients undergoing orthopedic lower limb surgery under spinal anesthesia.

Objectives

Primary Objective

- To evaluate the effect of Trendelenburg 20-degree position, passive leg raising at 45 degrees, and supine position on mean arterial pressure (MAP) and heart rate (HR) within 5 minutes after tourniquet deflation.

Secondary Objectives

* To compare systolic blood pressure (SBP) among the three groups after tourniquet deflation.
* To compare diastolic blood pressure (DBP) among the three groups after tourniquet deflation.
* To assess the need for vasopressor use in each group.
* To compare the amount of intravenous fluids administered in each group.
* To observe and document any complications occurring in each group.

MATERIALS AND METHODS

Study Area

This study was conducted in the Department of Anaesthesiology, Deen Dayal Upadhyay Hospital, Hari Nagar, New Delhi.

Study Design

A prospective, interventional, randomized, parallel controlled study was designed to evaluate the hemodynamic effects of different patient positions before tourniquet deflation in patients undergoing orthopedic lower limb surgery under spinal anesthesia.

Study Duration

The study was carried out from May 2022 to July 2024.

Study Population

The study included ASA physical status I and II patients aged between 18 and 60 years who were scheduled for orthopedic lower limb surgeries under spinal anesthesia.

Sample Size Estimation

Sample size was calculated based on previous data reported by Ahme Mohammed Sonbol et al.[1] Considering heart rate (HR) and mean arterial pressure (MAP) values in Trendelenburg and Passive Leg Raising positions, with 90% power and a 5% significance level, the minimum sample size required was 27 patients per group. To minimize error, 30 patients per group were enrolled, resulting in a total sample size of 90.

Inclusion Criteria

* ASA physical status I and II
* Age 18–60 years, both sexes
* Patients undergoing orthopedic lower limb surgery with tourniquet use under spinal anesthesia
* Surgery duration exceeding one hour

Exclusion Criteria

* History of cardiovascular illness
* Bilateral lower limb surgery
* Allergy to local anesthetics
* Contraindications to spinal anesthesia
* Lower limb vascular surgeries
* Surgeries exceeding allowable tourniquet time

* Intraoperative hemodynamic instability

Randomization

Patients were randomized using block randomization with a sealed envelope system. Fifteen envelopes (five per group) containing allocation to Trendelenburg (T), Passive Leg Raising (P), or Control © groups were prepared. Upon patient consent, an envelope was opened to determine group allocation.

Group Allocation

Group T: Trendelenburg position with 20° head-down tilt before tourniquet deflation (n=30)
Group P: Passive leg raising to 45° angle before tourniquet deflation (n=30)
Group C: Supine position as control group before tourniquet deflation (n=30)

Pre-Anesthetic Evaluation

All patients underwent thorough clinical history taking, physical examination, and investigations including complete blood count, renal function tests, blood sugar, urine examination, chest X-ray (P-A view), and baseline ECG for patients above 35 years as per hospital protocol.

Materials

Standard anesthesia machines and monitors, intravenous cannulas, 0.5% heavy bupivacaine, pneumatic tourniquet, sterile wedges for positioning, angle level meter app for precise tilt measurement, and emergency drugs were used.

Methodology

After baseline monitoring (HR, SBP, DBP, MAP, SpO_2, and ECG) and IV access, spinal anesthesia was administered at L3-L4 with 0.5% heavy bupivacaine using a 25G Quincke needle in sitting position. Oxygen was administered at 5 L/min via face mask. Tourniquet was inflated to 100 mmHg above systolic pressure after limb exsanguination with Esmarch bandage. Hemodynamics were continuously monitored intraoperatively.

Before tourniquet deflation, patients were positioned according to group allocation and maintained for 5 minutes after deflation. Hemodynamic parameters were recorded at baseline (0 minute) and at 1, 2, 3, 4, 5, 10 minutes and every 10 minutes up to 30 minutes post-deflation. The need for vasopressor administration (Mephentermine 6 mg bolus) and adverse events were documented.

Patients requiring general anesthesia due to inadequate block or those with hemodynamic instability were excluded.

Statistical Analysis

Data were analyzed using SPSS version 21.0. Continuous variables were expressed as mean ± SD or median and compared using ANOVA or nonparametric tests if normality was not met. Categorical variables were compared with Chi-square or Fisher's exact test. A p-value < 0.05 was considered statistically significant.

Results

This prospective randomized study included a total of 90 patients undergoing lower limb orthopaedic surgery under spinal anaesthesia. The patients were randomized into three groups of 30 each:

* Group T: Trendelenburg position (20° head-down tilt)
* Group P: Passive Leg Raising (PLR) (45° leg elevation)
* Group C: Supine position (control)

After exclusions (1 from Group P and 2 from Group C), data analysis was performed on the remaining 87 patients.

The demographic variables such as age, gender, height, weight, and ASA physical status were comparable between the three groups with no statistically significant difference [table 1].

Table 1: Demographic profile

Parameter Group T (n=30) Group P (n=29) Group C (n=28)

Parameter	Group T (n=30)	Group P (n=30)	Group C (n=30)	p-value
Age (years)	39.2 ± 10.4	40.1 ± 11.2	38.7 ± 9.8	0.78
Weight (kg)	66.5 ± 8.7	67.3 ± 7.9	65.8 ± 9.2	0.81
Height (cm)	168.2 ± 6.1	169.1 ± 5.7	167.5 ± 6.4	0.69
Gender (M/F)	18/12	19/11	17/13	0.91
ASA I/II	22/8	21/9	23/7	0.84

The duration of surgery and tourniquet time were comparable across the groups, indicating procedural consistency [table 2].

Table 2: Intraoperative Variables

Parameter	Group T	Group P	Group C	p-value
Surgery Duration (min)	74.5 ± 13.6	76.8 ± 12.2	75.2 ± 14.1	0.73
Tourniquet Time (min)	67.3 ± 11.4	68.5 ± 10.7	66.9 ± 12.0	0.81
Crystalloids (L)	1.90 ± 0.40	2.33 ± 0.47	2.14 ± 0.67	0.007

Following tourniquet deflation, hemodynamic parameters were recorded at predefined time points. The Trendelenburg group showed more stable systolic and mean arterial pressures [table 3].

Table 3: Hemodynamic Parameters Post-Tourniquet Deflation (Mean ± SD)

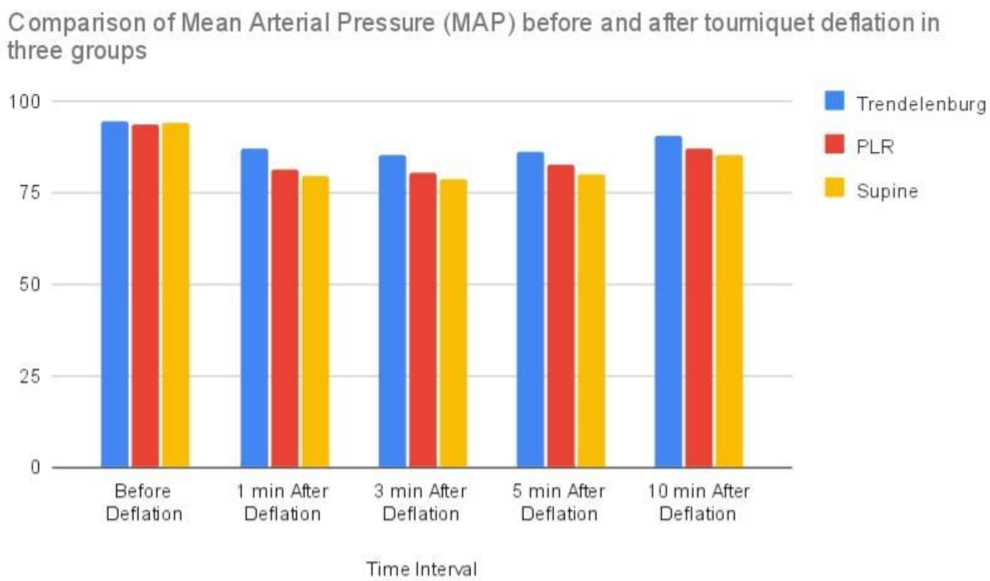
Time Point	SBP (mmHg) Group T	Group P	Group C	MAP (mmHg) Group T	Group P	Group C
Baseline	124.5 ± 9.2	125.1 ± 8.7	123.8 ± 9.6	89.6 ± 6.8	90.1 ± 7.1	89.0 ± 6.9
1 min post-def	119.8 ± 10.4	113.2 ± 12.1	110.7 ± 13.0	85.7 ± 7.4	78.5 ± 9.3	75.2 ± 9.9
5 min post-def	121.3 ± 9.9	115.4 ± 11.6	112.6 ± 12.8	87.2 ± 6.9	81.3 ± 8.5	77.6 ± 9.4
10 min post-def	123.1 ± 8.7	118.9 ± 9.4	115.8 ± 11.2	88.4 ± 7.2	83.1 ± 7.6	80.5 ± 8.3

Vasopressor use and incidence of hypotension/tachycardia were recorded. Fewer patients in Group T required vasopressors, though this was not statistically significant [table 4].

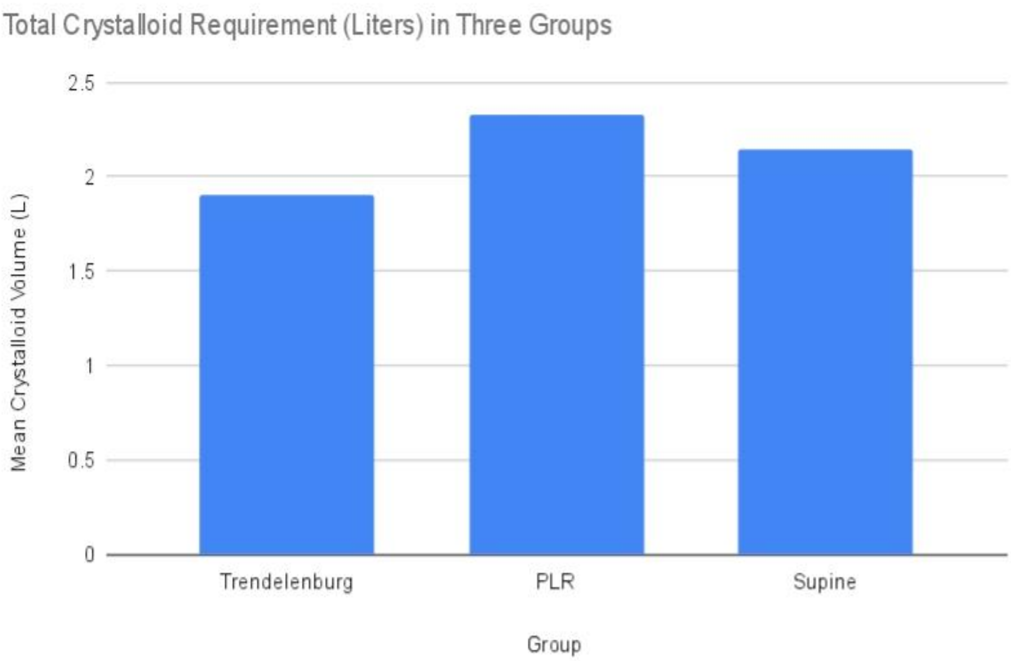
Table 4: Clinical Events Post-Deflation

Parameter	Group T	Group P	Group C	p-value
Vasopressor Use (n)	0	3	5	0.08
Hypotension Episodes	1	4	6	0.06
Tachycardia Episodes	2	5	6	0.09

Bar graph 1: Comparison of Mean Arterial Pressure (MAP) before and after tourniquet deflation in three groups



Bar graph 2: Total Crystalloid Requirement (Liters) in Three Groups



Discussion

The pneumatic tourniquet Is routinely used in orthopedic lower limb surgeries to minimize intraoperative bleeding, maintain a dry surgical field, and facilitate the identification of anatomical structures [9]. However, its use is associated with various physiological and hemodynamic changes, such as hypotension, tachycardia, and increased cardiac index. Metabolic alterations, including a transient rise in end-tidal CO2 (EtCO2), partial pressure of arterial CO2 (PaCO2), decreased pH, and lactic acidosis, have also been reported [10].

Several strategies are employed to mitigate the severity and duration of organ hypoperfusion following hypotension after tourniquet deflation. These include fluid resuscitation with colloids or crystalloids and the use of vasopressors. However, the hemodynamic response to fluid replacement may be delayed. As a result, various physical maneuvers such as the Trendelenburg position or passive leg raising (PLR) are often used as immediate interventions for hypotension and shock [11].

Despite the widespread use of these maneuvers, there is a paucity of studies directly comparing Trendelenburg and PLR positions in preventing cardiovascular adverse effects associated with tourniquet deflation during lower limb orthopedic surgeries. The current study was conducted to address this gap by comparing the effects of Trendelenburg (20 degrees), PLR (45 degrees), and a control group (supine position) on hemodynamic changes following tourniquet release in patients undergoing lower limb surgery under spinal anesthesia.

A total of 90 patients were enrolled and block-randomized into three groups. Following randomization, three patients were excluded: one from Group P due to the requirement of general anesthesia and two from Group C, one due to conversion to general anesthesia and another for exceeding a tourniquet time of two hours.

There were no statistically significant differences among the three groups with respect to demographic variables such as age, gender, height, or ASA physical status classification. Likewise, there was no statistical difference in the indications for surgery, duration of surgery, or tourniquet inflation time.

Although vasopressor use did not differ significantly among the three groups, it is noteworthy that no patient in the Trendelenburg group required vasopressors or exhibited complications such as hypotension or tachycardia. While the incidence of complications did not differ significantly between groups, the overall hemodynamic stability was better in the Trendelenburg group.

A statistically significant difference was observed in the amount of crystalloids administered among the groups ($p = 0.007$). The Trendelenburg group required a lower average fluid volume (1.9 ± 0.40 L) compared to the PLR (2.33 ± 0.47 L) and supine (2.14 ± 0.67 L) groups. This finding suggests that Trendelenburg positioning may reduce the need for aggressive fluid resuscitation. A meta-analysis by Geerts et al. supports this observation, concluding that both Trendelenburg and PLR positions improve cardiac output, with Trendelenburg increasing mean arterial pressure more effectively in the short term. However, PLR was shown to sustain the increase in cardiac output more consistently over time [12].

In the present study, the Trendelenburg group exhibited better maintenance of heart rate, mean arterial pressure (MAP), and systolic blood pressure (SBP) following tourniquet deflation compared to the PLR group. Interestingly, diastolic blood pressure (DBP) was better maintained in the supine group than in the Trendelenburg or PLR groups.

These results are consistent with the findings of Sonbol et al., who reported that the Trendelenburg position was more effective than PLR in preventing cardiovascular disturbances following tourniquet deflation [13]. Our findings also align with those of Wong et al., who observed that straight leg raising resulted in a reduction in MAP due to decreased diastolic pressure [14].

Similarly, a study by Huang et al. reported that PLR failed to counteract the effects of tourniquet deflation in over half of the cases (54.28%), with MAP decreasing by more than 5%. The authors noted that the development of hypotension was multifactorial and that PLR alone was insufficient to prevent hemodynamic compromise [15].

Another practical advantage of the Trendelenburg position observed in our study was its ease of application in the operating room setting. Unlike PLR, which can be cumbersome due to the need to maintain surgical sterility, Trendelenburg positioning can be quickly and safely implemented without disrupting the sterile field.

In summary, the Trendelenburg position demonstrated superior hemodynamic stability and reduced fluid requirements compared to PLR and supine positions following tourniquet deflation in lower limb orthopedic surgeries under spinal anesthesia. While there were no significant differences in vasopressor use or incidence of complications among the groups, the Trendelenburg position appeared to offer the most favorable profile. Despite the limitations, including a relatively small sample size and lack of invasive hemodynamic monitoring, our findings suggest that Trendelenburg positioning may be a simple and effective strategy for managing post-tourniquet hypotension in clinical practice.

To our knowledge, this is one of the few studies directly comparing Trendelenburg, PLR, and supine positions in this context. Further studies with larger sample sizes and continuous hemodynamic monitoring are warranted to validate these findings and determine long-term outcomes.

Conclusion

This prospective, randomized study demonstrates that the Trendelenburg position is more effective than passive leg raising and supine positioning in maintaining hemodynamic stability following tourniquet deflation during lower limb surgeries under spinal anesthesia. Patients in the Trendelenburg group exhibited more stable systolic and mean arterial blood pressures, lower fluid requirements, and reduced need for vasopressors compared to the other two groups. Although diastolic blood pressure was better preserved in the supine group, the overall hemodynamic profile favored the Trendelenburg position. Furthermore, its ease of implementation without compromising surgical sterility makes it a practical choice in the intraoperative setting. While no major complications were observed across groups, larger-scale studies with advanced hemodynamic monitoring are needed to further validate these findings and establish clinical guidelines.

Conflict of interest: Nil

Funding: Nil

Bibliography

1. Estebe J.P., Davies J.M., Richebe P. "The pneumatic tourniquet: Mechanical, ischaemia-reperfusion and systemic effects," European Journal of Anaesthesiology, 2011; 28(6): 404–411.
2. Horlocker T.T., Hebl J.R. "Modern pneumatic tourniquet use in upper and lower extremity surgery," Journal of the American Academy of Orthopaedic Surgeons, 2001; 9(6): 345–351.
3. Klenerman L. "The tourniquet in surgery," Journal of Bone and Joint Surgery British Volume, 1962; 44(4): 937–943.
4. Pedowitz R.A., Gershuni D.H., Crenshaw A.G. "Muscle injury associated with tourniquet use: A review of the current literature," Clinical Orthopaedics and Related Research, 1991; 267: 58–67.
5. Doussot A., Heyer L., Montcriol A. "Hemodynamic effects of pneumatic tourniquet release in orthopedic surgery: A review," Anesthésie&Réanimation, 2014; 60(7–8): 548–555.
6. Trendelenburg F. "Operation beiProlapsus uteri," ChirurgischeOperationslehre, 1890; 3: 379–389.

7. Stone M.B., Huang J., Jenne H. "Ultrasound determination of the effect of Trendelenburg positioning on the internal jugular vein cross-sectional area," American Journal of Emergency Medicine, 2010; 28(2): 202–205.
8. Marik P.E., Rivera R. "The effects of Trendelenburg position on hemodynamics and gas exchange: A systematic review," Critical Care Medicine, 2013; 41(1): 404–407.
9. Ralte P., "Pneumatic tourniquets in orthopaedic surgery – A review," Medical Journal Armed Forces India, 2015; 71(2): 177–181.
10. Tuncali B., "The effects of tourniquet use in lower extremity surgery on hemodynamics and blood gases," Anesthesia Essays and Researches, 2006; 60(4): 385–389.
11. Maheshwari V., "A review of non-pharmacological methods for treating intraoperative hypotension," Journal of Anaesthesiology Clinical Pharmacology, 2018; 34(3): 307–312.
12. Geerts B.F., "Should we reconsider the Trendelenburg position to treat hypotension? A systematic review," Resuscitation, 2011; 82(5): 545–549.
13. Sonbol H., "Comparative study of Trendelenburg and passive leg raising on hemodynamic parameters after tourniquet deflation," Egyptian Journal of Anaesthesia, 2019; 35(1): 15–20.
14. Wong D.H., "Effect of passive leg raising on systemic hemodynamics and its clinical significance," Critical Care Medicine, 1990; 18(11): 1143–1146.
15. Huang Y.S., "Evaluation of passive leg raising as a predictor of fluid responsiveness after tourniquet release in orthopedic surgeries," Journal of Clinical Monitoring and Computing, 2017; 31(6): 1231–1237.