

The Influence Of The Infusion Of Ephedrine And Phenylephrine On The Hemodynamic Stability After Subarachnoid Anesthesia In Senior Adults - A Controlled Randomized Study

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Abstract

ABSTRACT Study objective: We studied the influence of ephedrine or phenylephrine infusion given immediately after spinal anesthesia (SA) on hemodynamics in elderly orthopedic patients. Design: A prospective, randomized, double-blind, placebo-controlled study. Intervention: After subarachnoid injection of 15 mg of levobupivacaine the participants received either an infusion of ephedrine 20 mg (E group), phenylephrine 250 mcg (P group) or saline (C group) within 30 minutes. For 15 minutes before and 30 minutes after SA we measured blood pressure, cardiac index (CI) and heart rate (HR). Results 70 patients were included in the final analysis. At the end of measurements mean arterial pressure decreased significantly after SA in comparison to baseline in the C group but was maintained in the P and the E group, with no significant differences between the groups. CI decreased after SA in the C group was maintained in the P group and increased significantly in the E group, with significant differences between the C and the E group ($p=0.049$) and between the P and the E ($p=0.01$) group at the end of measurements. HR decreased significantly after SA in the C and the P group and was maintained in the E group, with significant differences between the P and the E group ($p=0.033$) at the end of measurements. Conclusions Hemodynamic changes after SA in elderly orthopedic patients can be prevented by an immediate infusion of phenylephrine or ephedrine. In addition to maintaining blood pressure the ephedrine infusion also maintains HR and increases CI after spinal anaesthesia. Key words: spinal anesthesia, hemodynamic stability, phenylephrine, ephedrine Trial registration: ISRCTN registry ISRCTN44377602. Registered on 15 June 2017.

Background

According to the national arthroplasty registers of many European countries, England, Australia and Canada, the prevalence of the hip and knee arthroplasty has increased in number over the past decades [1, 2, 3, 4]. Projections of primary and revision hip and knee arthroplasty in the United States until the year 2030 are estimated to grow by 174% for primary total hip arthroplasties and 673% for primary total knee arthroplasties from the year 2005 [3].

The available data from European registers shows the mean age at hip replacement surgery varied between 64 years in Romania and 71 years in Germany. For knee replacement, the mean age at surgery varied between 66 years in Slovakia and 72 years in Catalonia. The proportion of patients with ASA 3-4 differed substantially and ranged from 14% in the Netherlands to 38% in Finland [1].

A commonly used technique for elderly patients undergoing orthopedic surgery is spinal anesthesia (SA) [5, 6]. SA causes a sympathetic block by the block of preganglionic sympathetic nerve fibers [7]. Hypotension is a side effect often associated with SA [8]. The incidence of SA-induced hypotension (SAIH) in the elderly is almost 80% [9] and is due to a decrease of both the systemic vascular resistance (SVR) as well as cardiac output (CO) [5]. Due to decreased afterload, there may be an initial increase in CO [10]. Alternatively, there may be a fall in CO associated with decreased preload [11]. A biphasic change in CO after SA has been shown in elderly patients [12]. The elderly are at high risk for hypoperfusion caused

by hypotension, because of the high incidence of comorbid conditions [5, 13, 14]. One of the main risk factors for hypotension is hypovolemia [15,16] but the administration of crystalloids can quickly lead to volume overload and signs of congestive heart failure in the elderly and is often not effective in maintaining blood pressure [5]. Therefore, ephedrine and phenylephrine are the vasopressors of choice for the prevention of SAIH in the elderly [9]. Ephedrine is a direct and indirect α in β -receptor agonist. It has a slow onset [7] but a relatively long duration of action [17]. Phenylephrine is a direct α_1 -receptor agonist with a known beneficial effect during SA for the cesarean delivery [5, 18-21].

The objective of our study was to evaluate the effectiveness of prophylactic intravenous (IV) ephedrine or phenylephrine infusion on the prevention of hypotension and a decrease in CO following SA in patients older than 60 years undergoing elective orthopedic surgery.

Methods

Our prospective, randomized, double-blind, placebo-controlled study was approved by the National Medical Ethics Committee at the Ministry of Health, Republic of Slovenia (protocol number 0120-8/2017-3, KME 21/01/17). The trial was retrospectively registered at ISRCTN with the submission number ISRCTN44377602. We studied 84 patients older than 60 years, scheduled for orthopedic hip or knee replacement surgery under SA. Written informed consent was obtained from each patient. Participant exclusion criteria were any contraindications to SA (absolute: patients' refusal, infection at the site of injection, uncorrected hypovolemia, allergy, increased intracranial pressure or relative: coagulopathy, sepsis, fixed CO states, indeterminate neurological disease) or administration of vasoconstrictors (allergy or hypersensitivity to vasoconstrictors, unstable angina, recent coronary artery bypass surgery, recent myocardial infarction refractory arrhythmias, untreated or uncontrolled severe hypertension, untreated or uncontrolled heart failure, uncontrolled hypothyroidism, sulfite sensitivity, uncontrolled diabetes, pheochromocytoma, use of cocaine, monoamine oxidase inhibitors, phenothiazine compounds or tricyclic antidepressants).

Patients were fasted the night before the surgery. Antihypertensive medications were discontinued the day before the surgery, except the β -blockers. Midazolam 7.5 mg was given for premedication one hour before the surgery. After the patient arrival in the operating room, an IV line was inserted and the patient was placed in the lateral decubitus position. Using the paramedian approach with a 25-gauge Sprotte needle (PAJUNK, GmbH, Geisingen, Germany) lumbar puncture was performed at the L2–L3 interspace. With the needle aperture oriented in the cephalad direction, 3mL of 0.5% levobupivacaine (Chirocaine 0.5% plain; AbbVie, Campoverde, Italia) were injected within 15 seconds.

All the patients received an infusion of 1000 mL lactated Ringer solution within 45 minutes from the beginning of the measurement (500 ml before and 500 ml after SA). With respect to the infusion of treatment medication, the patients were randomly assigned to one of the three groups using sealed envelope randomization. The C group (control group) received an infusion of 30 ml 0.9% NaCl 30 minutes after SA. The P group (phenylephrine group) received a continuous infusion of 30 ml of 0.9% NaCl with

250 mcg of phenylephrine 30 minutes after SA. The E group (ephedrine group) received a continuous infusion 30 ml of 0.9% NaCl with 20 mg of ephedrine 30 minutes after SA. The infusion of the treatment medication in all the groups was started immediately after SA.

We measured non-invasive blood pressure, non-invasive CO using thoracic electrical bioimpedance (TEB) method, heart rate and pulse oximetry (SpO₂) using the AESCULON, OSYPCA MEDICAL, 2011, monitor.

Hemodynamic measurements were started 5 minutes after placing the patient in the lateral decubitus position and were recorded for 45 minutes (for 15 minutes before and 30 minutes after the injection of the local anesthetic solution into the subarachnoid space). Data on blood pressure were recorded and stored on the hard drive at 5-minute intervals and other hemodynamic data at 1-minute intervals.

The protocol for rescue treatment in the event of hemodynamic instability included:

1. Severe hypotension (decrease of systolic blood pressure for more than 30% from baseline, or systolic blood pressure less than 80 mmHg): additional ephedrine boluses of 5 mg repeated in 3 minutes with additional infusion of Ringer solution or additional phenylephrine boluses of 50 mcg repeated in 3 minutes with additional infusion of Ringer solution.
2. Bradycardia (≤ 50 beats per minute): bolus of atropine 0.5 mg, repeated in 1 minute until heart rate frequency is more than 50 beats per minute or overall amount of 2 mg atropine is reached.
3. Hypertension (increase of systolic blood pressure for more than 30% from baseline): discontinuation of the ongoing infusion.

Hypotensive, hypertensive or bradycardic patients were defined as patients who developed at least one episode of hypertension, hypotension or bradycardia throughout the case and were treated according to the protocol.

Data were analyzed with the SPSS 25.0.0. software. Demographic data and baseline values were compared with one-way analysis of variance and χ^2 , where appropriate. The hemodynamic data before, 10, 20 and 30 minutes after SA were compared with ANOVA with Bonferroni correction for post hoc comparisons and the Student's t-test for paired samples, where appropriate. In addition, the analysis of variance for repeated measurements with Bonferroni correction was performed to compare the change in hemodynamic measurements between the three treatment groups and the change over time. $P < 0.05$ was considered statistically significant.

Sample size calculation to detect a 20% difference in CI (0.5 L/min/m²) between treatment groups, assuming a mean CI of 2.5 L/min/m² and SD of 0.5 L/min/m² with a probability level of 0.05 and a power of 0.85, yielded a sample size of 69 patients. The same number of patients would detect a 10mmHg difference between the groups in MAP (assuming SD of 10 mmHg) with a probability level of

0.05 and a power of 0.85. Expecting dropouts due to various reasons, including complications, we randomized 90 patients. We used the G Power 3.1.9.2. software for these calculations.

Results

We randomized 90 patients. Four patients were excluded because they declined to participate and two patients were excluded for not meeting the inclusion criteria (Figure 1). Patients developing complications requiring a rescue protocol were excluded from final analysis and were analyzed separately. Seven patients from the C group were excluded because of hemodynamic instability (5 patients got severe hypotension, one had bradycardia and one had hypotension with bradycardia). Two patients were excluded from the P group because of hypotension with bradycardia and two had hypotension episode alone. Two patients were excluded from the E group because of hypotension, one patient because of bradycardia and hypotension. Therefore, 70 patients were included in the final analysis: Twenty-five patients in the E group, twenty-four in the P group and twenty-one patients in the C group.

There were no significant differences between the groups with respect to the demographic data and baseline hemodynamics (Table 1).

Hemodynamic changes after SA are shown in Table 2. Systolic arterial pressure (SAP) decreased significantly in comparison to baseline values in the C group 10, 20 and 30 minutes after SA ($p \leq 0.001$). In the P group, SAP decreased significantly 20 minutes after the block ($p \leq 0.03$) and returned to baseline at the end of measurements. There were no statistically significant differences in SAP after SA in the E group (Table 2). After spinal anesthesia, SAP was significantly decreased in the C group in comparison to the E group and P group, but there were no significant differences between the P group and E group. MAP decreased after SA in the C group and P group but was maintained in the E group. The decrease in MAP was statistically significant 10, 20 and 30 minutes after SA in the C group ($p \leq 0.001$) and 10 ($p=0.002$) and 20 minutes after SA ($p=0.023$) in the P group. There were no statistically significant differences in MAP after between the treatment groups (Table 2).

CI decreased significantly after SA in comparison to baseline values in the C, was maintained in the P group and increased significantly in the E group (Table 2). At the end of measurements, CI was significantly higher in the E Group in comparison to the C group ($p=0.049$) and the P group ($p=0.01$). Heart rate (HR) decreased significantly after SA with respect to baseline values in the C group and P Group but not in the E group of patients (Table 2). At the end of measurements, HR was significantly decreased in the P group in comparison to the E group ($p=0.033$). Stroke volume index (SVI) was maintained after SA in comparison to baseline values in the C group, transiently increased in the P group (10 minutes after spinal block $p=0.037$) and then returned to baseline values. In the E group, SVI increased significantly 10 ($p=0.07$) and 20 ($p=0.01$) minutes after SA (Table 2). 20 minutes after spinal anesthesia, SVI was significantly higher in the E group in comparison to the P group ($p=0.09$).

The change in hemodynamic data after spinal block in the three treatment groups is shown in Figure 2. The decrease in MAP after spinal block was most prominent in the C group and was statistically significant 10, 20 and 30 minutes after the block. In the P group, a transient statistically significant decrease in MAP was measured 10 ($p=0.002$) and 20 ($p=0.02$) minutes after the block, but by the end of measurements MAP returned to about baseline values. MAP was maintained after SA in the E group. At the end of measurements, the decrease in MAP was significantly higher in the C group compared to the E ($p=0.004$) and P group ($p=0.043$), but there were no differences between the P and E group (Figure 2).

The percentage in CI after SA decreased non-significantly in the C and P group (Figure 2). In the E group of patients, the percentage in CI significantly increased after SA. At the end of measurements, the percentage in CI was significantly increased in the E group in comparison to the C ($p=0.001$) and P group ($p=0.002$), with no differences between the C and P group. HR decreased significantly after SA in the C and P group but not in the E group (Figure 2). At the end of measurements, the decrease of HR after SA was significantly higher in the C ($p=0.017$) and P group ($p=0.013$) in comparison to the E group, with no significant differences between the C and P group (Figure 2). The percentage in SVI did not change after SA in the C group, transiently increased (10. minutes after the block) in the P group ($p=0.036$) and increased significantly in the E group ($p=0.049$; Figure 2). 20 minutes after SA the increase in SVI was significantly higher in the E group in comparison with the C ($p=0.02$) and P group ($p=0.48$) (Figure 2).

Fourteen patients developed complications (Table 3). There were no significant differences between groups. The incidence of bradycardic and hypotensive events ($n=14$) was not statistically different between the treatment groups ($p=0.33$). Although the number of the bradycardic ($n=3$) and the hypotensive ($n=6$) patients was higher in the group C, the differences between the groups did not reach statistical significance ($p=0.86$ and $p=0.53$). There were no significant differences between the groups with respect to the number of patients receiving ephedrine ($p=0.58$) or phenylephrine ($p=0.54$) as the rescue drug.

Discussion

We studied the influence of prophylactic treatment with two different vasopressors (ephedrine and phenylephrine) on the prevention of hypotension after SA and their changes on hemodynamics in the elderly patients.

The topic is undoubtedly very important. Buggy and co-workers [22] showed that regardless of prehydration, a high incidence of hypotension (the overall incidence of SAIH was 49%, ranging from 39% in the colloid group to 62% in the crystalloid group) follows SA in normovolemic elderly patients undergoing elective procedures. A definite and widely available method of predicting pre-operative hypotension is not identified yet. Berlac and Rasmussen suggested that NIRS could provide an early

warning of hypotension [23]. On the other hand, Hanss et al. reported that women who developed more severe hypotension after SA had greater changes in heart rate variability [24]. Especially the elderly are at increased risk of developing long-term complications from hypotension after SA [25] due to reduced physiological reserve and increased incidence of systemic disease [26]. Bijker et al. [27] showed that the mortality risk in elderly increases with extended duration of intraoperative hypotension. Our study shows the importance of prophylactic infusion treatment with vasopressors in this group of patients.

In our study, CO was measured with TEB, noninvasively. Most researchers have accepted the TEB method for monitoring the trends of change in CO, but the absolute value of CO measured with TEB is controversial [28-30]. As a non-invasive method in spontaneously breathing patients during SA, it has an advantage over invasive methods, which are ethically rarely justified [18]. In our study, the TEB method was used also as a trend monitor to follow the changes in hemodynamic parameters after three different methods of preventing hypotension after SA.

The incidence of patients developing complications was higher in the C group of patients (n=7) in comparison with the P group (n=4) and the E group (n=3). Although the differences were not statistically significant (due to a low sample size), a nearly double incidence of complications shows that hemodynamic complications after SA (bradycardia and hypotension) can be prevented with a prophylactic infusion of vasopressors. Since the main interest in our study was hemodynamics of vasopressors, we decided to exclude the patients with complications requiring rescue drugs in the final data presentation.

All the patients in our study were receiving a continuous infusion of Ringer's solution during the time of measurements. The study showed that the additional infusion of ephedrine maintained the MAP after SA (E group), the additional infusion of phenylephrine caused a temporary slight decrease in MAP (P group), but MAP returned to baseline at the end of measurements. In patients not receiving vasopressors (C group), MAP decreased after SA by about 14%. CI was maintained after SA in the C and P group and increased in the E group by about 14%. HR decreased after SA in the C and P group and was maintained in the E group.

Nakasuji et al. showed a decrease in SVR, not CO, is the main mechanism of hypotension seen during SA in elderly patients [31]. Marhofer and co-workers [32] also showed in elderly ASA 3 patients that the hypotension during SA was caused by a decrease in systemic vascular resistance index, but cardiac index did not change. Kamenik and Eržen [34] showed that CO decreases after SA in the group of middle-aged patients not receiving crystalloids as well as in the group of patients who received crystalloids before SA, while CO increases in the group of patients receiving lactated Ringer's solution at the time of spinal block. Later on, Zorko and Kamenik [35] have shown that the infusion of 1000 mL of lactated Ringer after spinal block prevented the decrease of CO after SA, CO was actually increasing while the infusion was running. In our study, we used a slightly modified hydration strategy. We infused 1000 ml of Ringers solution continuously during the period of measurements (15 minutes before and 30 minutes after SA). Our results show that with this regimen we were able to maintain CI after SA at about baseline values in the C group

of patients. However, in this group of patients we were not able to maintain the MAP. The MAP decreased due to a decrease in vascular resistance. In addition, HR also decreased after SA in the C group of patients. With an additional infusion of phenylephrine, which is a pure vasoconstrictor, we were able to prevent the decrease in vascular resistance. This resulted in only slight transient decrease in MAP. However, the infusion of phenylephrine did not prevent the decrease in HR after SA. In the study of Stewart et al., the authors found a dose-dependent reduction in both maternal HR and CO, measured with suprasternal Doppler, when comparing three different infusion regimens of phenylephrine. The highest infusion rate reduced both CO and HR by >20% [36]. In our study in the P group of patients, HR also decreased, but CI was maintained probably because of the continuous infusion of Ringers solution. In the E group of patients with the infusion of ephedrine, we were able to maintain the MAP and the HR and the CI increased due to the additional increase in SVI caused by the inotropic action of ephedrine.

The best vasopressor to be used after SA is still not known. The current opinion in obstetrics favors the use of phenylephrine over ephedrine as alpha agonist of choice for treating hypotension associated with SA due to its beneficial effect on fetal acid-base balance and umbilical pH [37,38]. On the other hand, Larson et al. [39] reviewed that many researchers suggest phenylephrine may adversely affect cerebral oxygen saturation and perfusion. The authors stated that the use of phenylephrine to treat SAIH is a ubiquitous practice among anesthesia providers, despite the fact that it has never been shown to improve outcomes. Another approach could be the combined use of the vasopressors and different timings, but according to Das et al. [40], in obstetric patients such combination of half the usual dose of ephedrine and phenylephrine had no supreme outcome.

Conclusions

In conclusion, our study shows that we can decrease the incidence of complications and the decrease in MAP after SA with the combination of the Ringers solution infusion with the infusion of ephedrine or an infusion of phenylephrine. An ephedrine infusion also prevents a decrease in HR and increases cardiac output, while an infusion of phenylephrine maintains CO, but is accompanied by a decrease in HR. Since flow is better maintained, we recommend the infusion of ephedrine in elderly receiving SA. Further studies are necessary to evaluate the duration of the effects of the infusion of ephedrine and the optimal dose to improve hemodynamic stability after SA in the elderly.

Abbreviations

ANOVA-analysis of variance

ASA-the American Society of Anesthesiologists

C group -control group

CI-cardiac index

CO-cardiac output

E group-ephedrine group

IV-intravenous

HR-heart rate

MAP-mean arterial pressure

NIRS-near-infrared spectroscopy

P group -phenylephrine group

pH-power of hydrogen

SA-spinal anesthesia

SAIH- spinal anesthesia induced hypotension

SAP-systolic arterial pressure

SD-standard deviation

SPSS- statistical package for the social sciences

SV-stroke volume

SVI-stroke volume index

SVR-systemic vascular resistance

TEB-thoracic electrical bioimpedancy

Declarations

Ethics approval: This study was approved by the National Medical Ethics Committee at Ministry of Health, Republic of Slovenia, 5 Štefanova Street, 1000 Ljubljana, Slovenia, Europe,

under reference number: 0120-8/2017-3, KME 21/01/17-bis.

Consent to participate: Written informed consent was obtained from all study participants.

Consent for publication: Not applicable.

Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no conflict of interest.

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Authors' contributions: MZ was the primary researcher. He has contributed to study design, patient recruitment, data collection, interpretation of the results and wrote the original draft of the manuscript. NKS has contributed to study design, interpretation of the results and revised the manuscript for important intellectual content. MK has contributed to study design, analyzed the data, interpreted the results and revised the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Tables

Table 1. Demographic data and baseline hemodynamic measurements in the three groups of patients

GROUP	C	P	E
Number of patients	21	24	25
Gender (male/female)	5/16	8/16	5/20
Age (years)	67.9 (\pm 5.5)	71.1 (\pm 7.7)	68.4 (\pm 6.6)
Height (cm)	166.2 (\pm 8.2)	158.8 (\pm 34.6)	164.6 (\pm 11.5)
Weight (kg)	79.7 (\pm 13.5)	86.0 (\pm 13.6)	82.1 (\pm 14.2)
BMI	28.8 (\pm 4.5)	31.3 (\pm 5.0)	30.2 (\pm 3.9)
BSA	1.9 (\pm 0.2)	1.9 (\pm 0.2)	1.9 (\pm 0.2)
SBP (mmHg) ^a	134 (\pm 22)	128 (\pm 17)	125 (\pm 15)
MAP (mmHg) ^a	90 (\pm 12)	85 (\pm 12)	84 (\pm 9)
HR (beats/min) ^a	75.4 (\pm 11.0)	73.5 (\pm 11.6)	74.7 (\pm 11.7)
CO (l/min) ^a	6.2 (\pm 1.1)	6.5 (\pm 1.1)	6.4 (\pm 0.9)
CI(BSA) (l/min/m²) ^a	2.5 (\pm 0.7)	2.2 (\pm 0.5)	2.5 (\pm 0.6)
SVR (din s cm⁻⁵) ^a	886 (\pm 292)	863 (\pm 233)	850 (\pm 320)
SI(BSA) (ml/m²) ^a	33.1 (\pm 5.8)	30.3 (\pm 6.0)	32.8 (\pm 6.7)

SBP = systolic blood pressure, MAP = mean arterial pressure, CO = cardiac output,

SVR = systemic vascular resistance

Values are mean (\pm SD)

^a Baseline values defined as last registered values before SA

Table 2. Systolic blood pressure (SAP), mean arterial pressure (MAP), hearth rate (HR), cardiac index (CI) and stroke volume index (SVI) at baseline, 10 min, 20 min and 30 min after spinal anesthesia in three groups of patients.

	Baseline	10 minutes after the block	20 minutes after the block	30 minutes after the block
ΔAP (mmHg)				
<i>Group C</i>	134 ± 22	110 ± 16 *† ¹⁺²	113 ± 15 *† ¹⁺²	113 ± 14*† ¹⁺²
<i>Group P</i>	128 ± 17	122 ± 18*† ¹	124 ± 17 † ¹	125 ± *19 † ¹
<i>Group E</i>	125 ± 15	125 ± 16 † ²	129 ± 16 † ²	126 ± 16 † ²
MAP (mmHg)				
<i>Group C</i>	90 ± 14	77 ± 13*	77 ± 13*	77 ± 12*
<i>Group P</i>	85 ± 12	79 ± 9*	81 ± 10*	81 ± 12
<i>Group E</i>	84 ± 9	80 ± 11	83 ± 12	82 ± 11
CI (BSA)				
[l/min/m²]				
<i>Group C</i>	2.5 ± 0.7	2.3 ± 0.5 *	2.3 ± 0.6 *	2.3 ± 0.6 *† ²
<i>Group P</i>	2.2 ± 0.5	2.2 ± 0.6 † ³	2.1 ± 0.5 † ³	2.1 ± 0.5 † ³
<i>Group E</i>	2.5 ± 0.6	2.7 ± 0.7 *† ³	2.7 ± 0.6 *† ³	2.7 ± 0.5 *† ²⁺³
HR (beats/min)				
<i>Group C</i>	75 ± 11	71 ± 12*	70 ± 12*	71 ± 12*
<i>Group P</i>	74 ± 12	69 ± 12*	68 ± 11*	69 ± 11 *† ³
<i>Group E</i>	75 ± 12	76 ± 12	75 ± 11	77 ± 11 † ³
SVI (BSA) [ml/n²]				
<i>Group C</i>	33 ± 6	32 ± 5	33 ± 6	33 ± 5

<i>Group P</i>	30 ± 6	32 ± 9*	31 ± 7 † ³	31 ± 6
<i>Group E</i>	33 ± 7	35 ± 7*	36 ± 6 *† ³	35 ± 7

Values are mean +/- SD.

* $P < 0.05$ with respect to baseline.

†¹ $P < 0.05$ between the Group P and Group C

†² $P < 0.05$ between the Group E and Group C

†³ $P < 0.05$ between the Group P and Group E

Table 3. Systolic blood pressure (SAP), mean arterial pressure (MAP), hearth rate (HR), cardiac index (CI) and stroke volume index (SVI) at baseline, 10 min, 20 min and 30 min after spinal anesthesia in three groups of patients.

	Baseline	10 minutes after the block	20 minutes after the block	30 minutes after the block
ΔAP (mmHg)				
<i>Group C</i>	134 ± 22	110 ± 16 *† ¹ † ²	113 ± 15 *† ¹ † ²	113 ± 14*† ¹ † ²
<i>Group P</i>	128 ± 17	122 ± 18*† ¹	124 ± 17 † ¹	125 ± *19 † ¹
<i>Group E</i>	125 ± 15	125 ± 16 † ²	129 ± 16 † ²	126 ± 16 † ²
MAP (mmHg)				
<i>Group C</i>	90 ± 14	77 ± 13*	77 ± 13*	77 ± 12*
<i>Group P</i>	85 ± 12	79 ± 9*	81 ± 10*	81 ± 12
<i>Group E</i>	84 ± 9	80 ± 11	83 ± 12	82 ± 11
CI (BSA)				
[l/min/m²]				
<i>Group C</i>	2.5 ± 0.7	2.3 ± 0.5 *	2.3 ± 0.6 *	2.3 ± 0.6 *† ²
<i>Group P</i>	2.2 ± 0.5	2.2 ± 0.6 † ³	2.1 ± 0.5 † ³	2.1 ± 0.5 † ³
<i>Group E</i>	2.5 ± 0.6	2.7 ± 0.7 *† ³	2.7 ± 0.6 *† ³	2.7 ± 0.5 *† ² † ³
HR (beats/min)				
<i>Group C</i>	75 ± 11	71 ± 12*	70 ± 12*	71 ± 12*
<i>Group P</i>	74 ± 12	69 ± 12*	68 ± 11*	69 ± 11 *† ³
<i>Group E</i>	75 ± 12	76 ± 12	75 ± 11	77 ± 11 † ³
SVI (BSA) [ml/n²]				
<i>Group C</i>	33 ± 6	32 ± 5	33 ± 6	33 ± 5

<i>Group P</i>	30 ± 6	32 ± 9*	31 ± 7 † ³	31 ± 6
<i>Group E</i>	33 ± 7	35 ± 7*	36 ± 6 *† ³	35 ± 7

Values are mean +/- SD.

* $P < 0.05$ with respect to baseline.

†¹ $P < 0.05$ between the Group P and Group C

†² $P < 0.05$ between the Group E and Group C

†³ $P < 0.05$ between the Group P and Group E

Figures

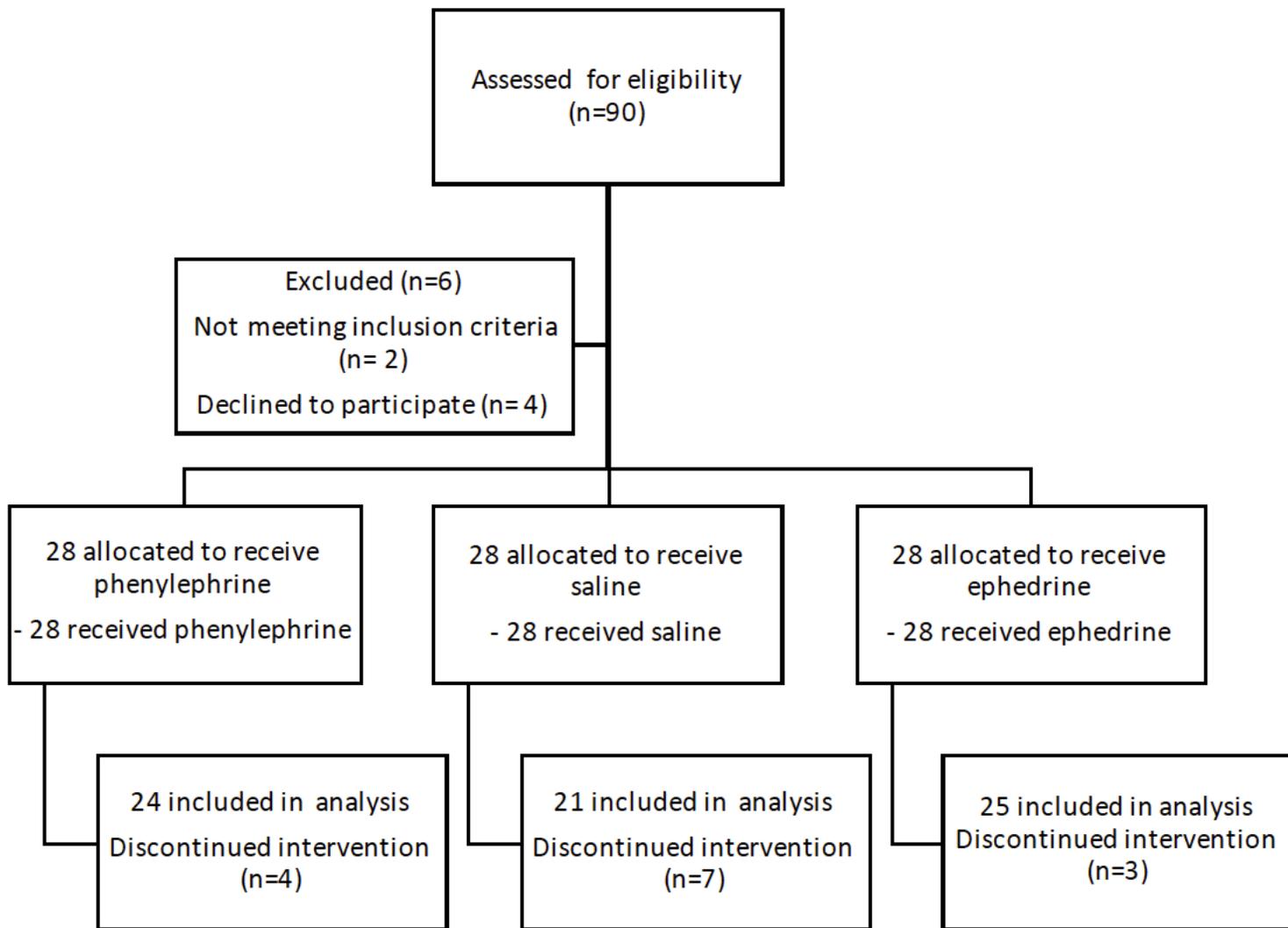


Figure 1

Randomization and follow-up of the patients.

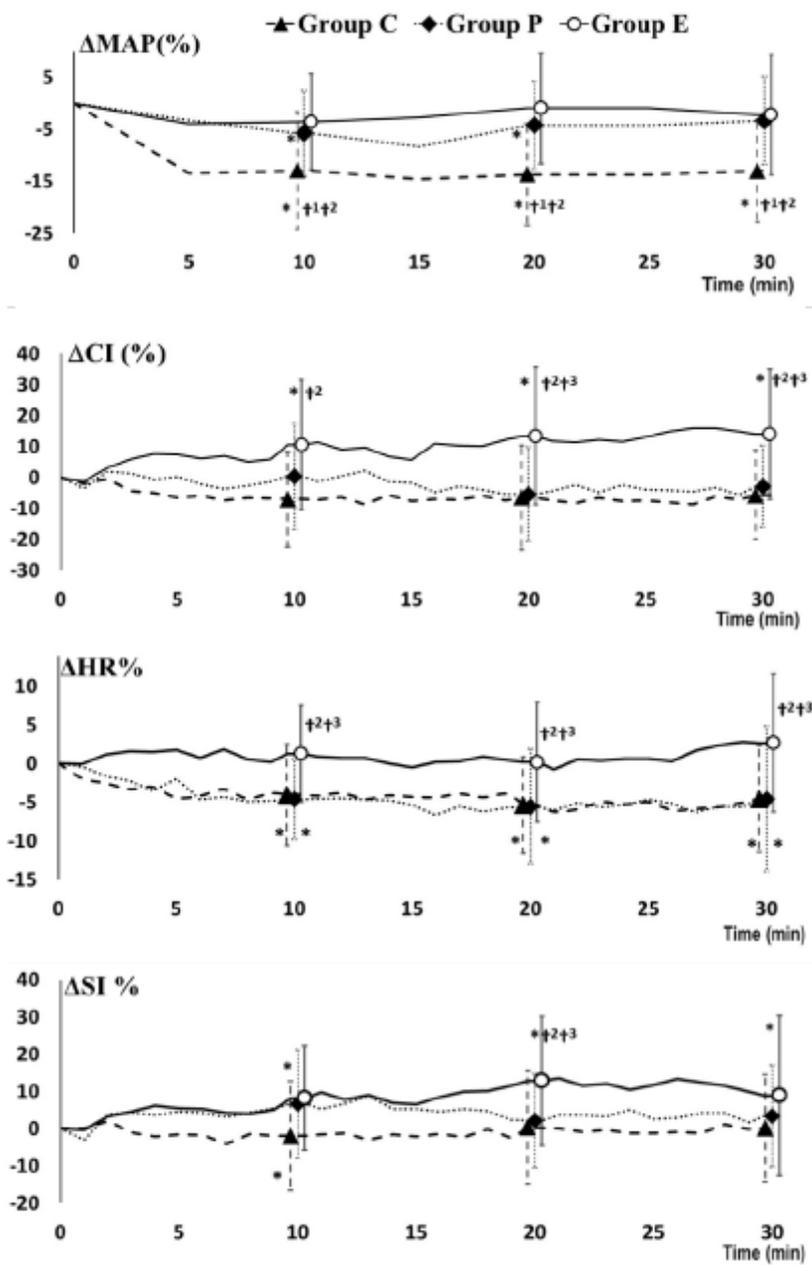


Figure 2

The change of mean arterial pressure (MAP), heart rate (HR), cardiac index (CI), and stroke volume index (SVI) from the baseline until 30 min after SA in three groups of patients (Group C = control group; Group P = phenylephrine group; Group E = ephedrine group).