DIFFERENCES IN HEMODYNAMIC PARAMETERS IN GENERAL AND SPINAL ANESTHESIA DURING LOWER LIMB ORTHOPEDIC SURGERIES

RAZLIKE U HEMODINAMIČKIM PARAMETRIMA KOD OPŠTE I SPINALNE ANESTEZIJE TOKOM ORTOPEDSKIH OPERACIJA DONJIH EKSTREMITETA

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Original study
UDK 616.718-089.5
https://doi.org/10.2298/MPNS2408222S

Abstract

Introduction. Hemodynamic instability is a frequent adverse effect during anesthesia and one of the significant parameters in determining the type of anesthesia. This study examined the incidence of hypotension and bradycardia during general and spinal anesthesia in hip and knee arthroplasty, alongside potential causes. We hypothesized that hypotension occurs more frequently with general anesthesia, while bradycardia is more prevalent with spinal anesthesia. **Material and Methods.** This retrospective study included patients who underwent total hip or knee alloarthroplasty. Data regarding blood pressure, heart rate, long-term antihypertensive therapy, and comorbidities were extracted from medical records. Patients were divided into two groups based on the type of anesthesia administered: general or spinal anesthesia. **Results.** Among 371 patients, 105 experienced bradycardia, and 308 developed hypotension based on systolic blood pressure measurements. Hypotension was significantly more common in patients receiving general anesthesia, with the lowest mean arterial blood pressure observed in 41 patients (59.4%). However, there was no significant difference in the incidence of bradycardia between spinal and general anesthesia. Similarly, no significant differences were identified in the incidence of hypotension and bradycardia between standard or unilateral spinal anesthesia. Chronic essential hypertension was associated with occurrence higher incidence of bradycardia (86.7%). Additionally, antihypertensive therapy was linked to increased occurrences of both hypotension (134 patients, 43.5%) and bradycardia (74 patients, 70.5%). **Discussion/Conclusion.** Intraoperative hypotension is more prevalent in patients undergoing general anesthesia. However, no significant difference in the occurrence of bradycardia was observed between general and spinal anesthesia. Essential hypertension and long-term antihypertensive therapy are potential risk factors for bradycardia and hypotension during anesthesia.

Key words: Hemodynamic Monitoring; Anesthesia, General; Anesthesia, Spinal; Hypotension; Bradycardia; Risk Factors

Sažetak

Uvod. Hemodinamička nestabilnost je čest neželjeni događaj tokom anestezije. Kako je ovo jedan od značajnih parametara pri izboru vrste anestezije, istraživali smo učestalost hipotenzije i bradikardije kod opšte i spinalne anestezije tokom aloartroplastike kuka i kolena kao i njihove potencijalne uzroke. Pretpostavili smo da je hipotenzija češća u opštoj, a bradikardija u spinalnoj anesteziji. **Materijal i metode.** Istraživanje je sprovedeno kao retrospektivna studija koja je obuhvatila pacijente kojima je izvršena aloartroplastika kuka ili kolena. Iz protokola za anesteziju su preuzeti podaci o vrednostima krvnog pritiska i pulsa, podaci o hroničnoj antihipertenzivnoj terapiji i komorbiditetima. Pacijenti su podeljeni u dve grupe prema vrsti anestezije (opšta i spinalna). **Rezultati.** Od ukupno 371 pacijenta, kod 105 se javila bradikardija, dok je kod 308 došlo do hipotenzije. Pacijenti koji su primili opštu anesteziju imali su značajno češće prisutnu hipotenziju prema vrednostima najnižeg zabeleženog srednjeg arterijskog pritiska (41; 59,4%). Nije pronađena statistički značajna razlika u pojavi bradikardije kod pacijenata u opštoj i spinalnoj anesteziji. Nije pronađena statistički značajna razlika u pojavi hipotenzije i bradikardije kod pacijenata koji su primili standardnu ili unilateralnu spinalnu anesteziju. Hronična esencijalna hipertenzija povezana je sa češćom pojavom bradikardije kod pacijenata (86,7%). Hronična antihipertenzivna terapija je povezana sa češćom pojavom hipotenzije (134, 43,5%) i bradikardije (74, 70,5%) kod pacijenata u toku anestezije. **Diskusija/Zaključak.** Hipotenzija se češće javlja kod pacijenata u opštoj anesteziji. Ne postoji statistički značajna razlika u pojavi bradikardije tokom opšte i spinalne anestezije. Značajni faktori rizika za pojavu hipotenzije i bradikardije tokom anestezije su hronična esencijalna hipertenzija i antihipertenzivna terapija.

Ključne reči: hemodinamski monitoring; opšta anestezija; spinalna anestezija; hipotenzija; bradikardija; faktori rizika

Introduction

Orthopedic surgeries can be performed under general anesthesia, neuraxial block (spinal anesthesia), or peripheral or central blocks. The choice of anesthesia is determined by anesthesiologists, considering factors such as the patient's general condition, age and previous anesthetic complications. The potential advantages and risks, including absolute and relative contraindications, are also taken into consideration [1].

Hemodynamic instability is a common adverse event during both general and spinal anesthesia [2].

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Abbreviations

ASA – American Society of Anesthesiologists
ACE – angiotensin-converting enzyme
ARB – angiotensin II receptor blocker
SBP – systolic blood pressure
MAP – mean arterial pressure
CCB – calcium chanel blocker

Both types of anesthesia suppress the sympathetic nervous system. If the patient is on antihypertensive therapy such as blockers of the renin-angiotensin-aldosterone system blockers (which also reduce adrenergic receptor sensitivity), the likelihood of refractory hypotension increases significantly [3].

Guidelines recommend maintaining systolic blood pressure during surgery at ≥90% of pre-anesthesia values, and preventing it from dropping below 80% [4]. The Oxford Handbook of Anesthesia recommends maintaining mean arterial pressure above 65 mmHg or 80% of baseline values during surgery [5].

The aim of this study was to analyze changes in hemodynamic parameters (blood pressure and heart rate) during general and spinal anesthesia in hip and knee alloarthroplasty. Three hypotheses were proposed before starting the research:

1. Hypotension is more frequent during general anesthesia than spinal anesthesia in hip and knee alloarthroplasty
2. Bradycardia is more frequent during spinal anesthesia than general anesthesia in hip and knee alloarthroplasty
3. Hypotension is more frequent in patients on chronic antihypertensive therapy (renin-angiotensin-aldosterone system inhibitors).

Material and Methods

The retrospective study was conducted at the Clinic for Anesthesia, Intensive Care and Pain Therapy, University Clinical Center of Vojvodina, after obtaining the approval of the University Clinical Center of Vojvodina Ethics Committee. The study covered the period from July 2022 to December 2022 and included medical records of 371 patients undergoing primary hip or knee alloarthroplasty.

The following data were extracted from the anesthesia protocols: procedure type, demographic data (sex, age, body mass, height), ASA (American Society of Anesthesiologists) status, comorbidities (essential arterial hypertension and diabetes mellitus), chronic antihypertensive therapy (angiotensin-converting-enzyme (ACE) inhibitors, beta blockers, calcium channel antagonists, diuretics, and angiotensin II receptor blockers (ARBs), type of anesthesia, blood pressure and heart rate. Comorbidities were recorded as they might contribute to blood pressure and heart rate values.

Blood pressure, heart rate, and their lowest recorded values were taken from the anesthesia protocols at the beginning of surgery. Patients were divided into two groups based on the type of anesthesia: 176 patients received general balanced anesthesia, while 195 received spinal anesthesia (57 of whom received unilateral spinal anesthesia). Patients receiving both general and spinal anesthesia were excluded from our study.

Hypotension during anesthesia was defined as a drop in systolic blood pressure >20% from baseline or a drop in mean arterial pressure < 65 mmHg. Like in previous studies, we used both definitions of hypotension to check for any differences. Bradycardia was defined as a drop in heart rate <50 beats per minute.

Descriptive statistics (measures of central tendency (arithmetic mean), variability (standard deviation), and relative numbers (structure indicators)) were used for the analysis of primary data. Predictive analyses included parametric (Student's t-test) and non-parametric tests. Hypotheses were tested at the statistical significance level of ($\alpha = 0.05$. Results are presented in tables and graphs. Data was processed using standard statistical packages (IBM SPSS Statistics 26).

Results

The study included 371 patients (146 males (39.4%), 225 females (60.6%)), aged 39 – 86 years. The median age of the patients is 68 years, and the mean value is 66.81 years. Of the total of 371 patients, 176 patients (47.4%) received balanced general anesthesia, and 195 patients (52.6%) received regional anesthesia (138 (70.8%) spinal, 57 (29.2%) unilateral spinal).

A statistically significant difference was observed in mean values of systolic blood pressure (SBP) ($t=-3.84$; $p<0.001$) and mean arterial pressure (MAP) ($t=-3.49$; $p<0.001$) between the groups of general and spinal anesthesia. No difference was observed in mean heart rate values in patients receiving different types of anesthesia ($t=1.67$; $p=0.09$). Mean SPB in patients under general anesthesia was 96.48±13.79, compared to 102.22±14.95 in patients under spinal anesthesia. Mean MAP in patients under general anesthesia was 72.97±11.31, compared to 77.24±12.05 in patients under spinal anesthesia.

There was no statistically significant difference in the mean pulse values ($t=0.05$; $p=0.96$). However, a statistically significant difference was observed in the mean values of the lowest SBP ($t=6.24$; $p<0.001$) and the lowest MAP ($t=5.08$; $p<0.001$) in patients who received standard spinal or unilateral spinal anesthesia. Specifically, the mean lowest SBP was 105.98±14.28

Table 1. Incidence of hypotension according to the mean arterial pressure

Type of anesthesia	Hypotension according to the MAP		Total	P
	Non-hypotensive	Hypotensive		
General	135	41	176	0.03
	44.7%	59.4%	47.4%	
Spinal	167	28	195	
	55.3%	40.6%	52.6%	
Total	302	69	371	
	100%	100%	100%	

MAP – mean arterial pressure

for patients under spinal anesthesia and 93.05±12.63 for those under unilateral spinal anesthesia. Similarly, the mean lowest MAP was 79.84±11.49 in the spinal anesthesia group and 70.50±11.19 in the under unilateral spinal anesthesia group.

In our study, 105 patients (28.3%) developed bradycardia (<50/min), while 308 patients (83%) experienced hypotension based on the SBP value recorded at the beginning of operation (a drop below 80% of the baseline value). Furthermore, 280 patients (75.5%) were hypotensive based on the MAP value recorded at the beginning of operation (a drop below 80% of the baseline value), and in 69 patients (18.6%), the MAP value fell below 65 mmHg.

There was no statistically significant difference in the frequency of bradycardia between the general anesthesia and spinal anesthesia groups (χ^2=0.002: p=0.99). Bradycardia occurred in 28.4% of patients under general anesthesia and in 28.2% of patients under spinal anesthesia.

There was no statistically significant difference in the frequency of hypotension based on the lowest recorded SBP between the general and spinal anesthesia group (χ^2=1.831; p=0.21). Based on SBP values, hypotension occurred in 151 patients (85.6%) who received general anesthesia and 157 patients (80.5%) who received spinal anesthesia.

However, hypotension based on the lowest recorded MAP occurred more frequently in the general anesthesia group (41; 59.4%) compared to the group of patients who received one form of regional anesthesia (167; 55.3%) (χ^2=4.88; p=0.03) **(Table 1).** Specifically, the frequency of hypotension based on MAP was 23.3% in the general anesthesia group and 14.4% in the spinal anesthesia group.

There was no statistically significant difference in the presence of bradycardia (χ^2=1.159; p=0.3), hypotension based on SBP (χ^2=1.53; p=0.24), or hypotension based on MAP (χ^2=0, 85; p=0.39) between patients who received spinal anesthesia and those who received unilateral spinal anesthesia.

A significant difference was found between hypertension as a comorbidity in patients with and the ones without bradycardia (χ^2=7.61; p=0.006). There was a higher percentage of hypertensive patients with bradycardia (86.7%) compared to the percentage of hypertensive patients with no bradycardia (73.3%).

It was found that significantly higher percentage of patients with diabetes mellitus did not develop bradycardia (21.1%) compared to the ones with diabetes mellitus who developed bradycardia (8.6%) (χ^2=8.12; p=0.004).

No significant differences were observed in the use of ACE inhibitors among patients with and without bradycardia (χ^2=0.005; p=0.941), or in patients with and without hypotension based on SBP (χ^2=0.25; p=0.619) or MAP (χ^2=0.07; p=0.79).

However, a higher percentage of patients who used calcium channel blockers developed bradycardia during the intervention (39%) compared to those who

Table 2. Incidence of bradycardia according to the use of calcium channel blockers and angiotensin receptor blockers

CCB	Bradycardia		Total	p	ARB	Bradycardia		Total	p
	No	Yes				No	Yes		
No	193	64	257	0.03	No	244	85	329	0.003
	72.6%	61%	69.3%			91.7%	81%	88.7%	
Yes	73	41	114		Yes	22	20	42	
	27.4%	39%	30.7%			8.3%	19%	11.3%	
Total	266	105	371		Total	266	105	371	
	100%	100%	100%			100%	100%	100%	

CCB – calcium channel blockers; ARB – angiotensin receptor blocker

Table 3. Incidence of bradycardia and hypotension according to the use of antihypertensive therapy

Antihypertensives	Bradycardia		Total	Hypotensive SBP		Total	p
	No	Yes		No	Yes		
No	194	31	225	51	174	225	<0.001
	72.9%	29.5%	60.6%	81%	56.5%	60.6%	
Yes	72	74	146	12	134	146	
	27.1%	70.5%	39.4%	19%	43.5%	39.4%	
Total	266	105	371	63	308	371	
	100%	100%	100%	100%	100%	100%	

SBP – systolic blood pressure

did not (27.4%) (χ^2=4.76; p=0.03) **(Table 2).** Similarly, a higher percentage of patients using ARBs developed bradycardia (19%) compared to those who did not (8.3%) (χ^2=8.71; p=0.003) **(Table 2).**

No statistically significant association was found between the use of ARBs and hypotension based on SBP (χ^2=1.87; p=0.17) or MAP (χ^2=1.8; p=0.18).

However, a statistically higher percentage of patients using antihypertensive therapy developed bradycardia (70.5%) compared to those who did not (27.1%) (χ^2= 59.44; p<0.001) **(Table 3).** Similarly, a higher percentage of patients using antihypertensives were hypotensive based on SBP (43.5%) compared to those who were not hypotensive (19%) (χ^2=13.11; p<0.001) **(Table 3).**

Discussion

In this study, 28.3% of patients developed bradycardia, while 83% developed hypotension based on their SBP. The frequency of hypotension during general anesthesia varies widely in the literature (16–93%) [6–9]. In our study, hypotension occurred in 86% of patients under general anesthesia based on SBP and in 23.3% based on MAP. For spinal anesthesia, hypotension occurred in 80.5% of patients based on SBP and 14.36% based on MAP, which is higher than previously reported frequencies of 16-33% [10]. This discrepancy may be attributed to variations in definitions of intraoperative hypotension and the use of different parameters (SBP vs. MAP). Moreover, Südfeld S et al. found that older age may be a potential risk factor for intraoperative hypotension, and the majority of patients included in our research belong to this age group [11].

Our findings support our first hypothesis that hypotension based on MAP occurs more frequently in patients under general anesthesia, consistent with the study by Messina et al. [12].

However, no significant difference in hypotension or bradycardia frequency was observed between patients who received standard spinal anesthesia and those who received unilateral spinal anesthesia, contrary to previous studies suggesting that unilateral blocks, compared to standard spinal anesthesia, can reduce the frequency of hemodynamic instability during orthopedic surgeries [13].

The occurrence of bradycardia was similar between general and spinal anesthesia, with rates of 28.4% and 28.2%, respectively. These results align with earlier studies reporting bradycardia frequencies of 9-74% during spinal anesthesia [14], and 27.3-34.7% during general anesthesia [15, 16]; therefore, our second hypothesis was not confirmed.

The results show that certain comorbidities are associated with the frequency of bradycardia occurrence. Specifically, bradycardia was more common in hypertensive patients (70.5%), likely due to the use of ARBs and calcium channel blockers, which our study proved to contribute significantly to intraoperative bradycardia.

Cardiovascular autonomic neuropathy, characterized by dysregulation of the sympathetic and parasympathetic nervous systems leading to cardiovascular and respiratory disorders, is a common complication in patients with diabetes mellitus. A recently published case report by Lee et al. described a diabetic patient who experienced a significant drop in blood pressure (70/40 mmHg) and a heart rate below 20 beats per minute after induction of anesthesia [17]. The *Oxford Handbook of Anesthesia* identifies autonomic neuropathy in diabetic patients as a risk factor for tachycardia, bradycardia, and postural hypotension [5]. While hemodynamic instability is an expected complication in such patients, our findings revealed an even rarer occurrence of bradycardia. This phenomenon could generally be attributed to a decrease in baroreceptor sensitivity in patients with diabetes mellitus.

A comparison of chronic antihypertensive therapy and intraoperative hemodynamic instability showed a higher incidence of bradycardia in patients on chronic therapy with ARBs and calcium channel blockers, consistent with a Canadian study from 2015 [15]. Our study demonstrated that chronic antihypertensive therapy is a significant factor in the development of hemodynamic instability, including both hypotension and bradycardia.

One study reported a significant incidence of hypotension in patients who received spinal anesthesia while on chronic antihypertensive therapy with calcium channel blockers, attributing this by the vasodilator effect of calcium blockers combined with spinal anesthesia. The same study also noted a higher incidence of bradycardia in patients on chronic beta-blocker therapy [18]. However, our findings differed: bradycardia was associated with the chronic use of calcium channel blockers. Importantly, our study examined the overall statistically significant occurrence of hemodynamic instability in patients on antihypertensive therapy rather than separating patients based on spinal or general anesthesia.

Some studies have observed severe circulatory side effects following anesthesia induction in patients on chronic ACE inhibitors and ARBs [15, 19]. While our study found occurrence higher incidence of bradycardia in patients on ARBs, it did not reveal a significant association between the chronic use of renin-angiotensin-aldosterone system blockers and intraoperative hypotension, failing to confirm our third hypothesis. Given the potential contribution of chronic antihypertensive therapy (ARBs and ACE inhibitors) to intraoperative hypotension, the *Oxford Handbook of Anesthesia* recommends discontinuing these medications 24 hours before surgery to reduce the risk of intraoperative cardiovascular instability [5]. The absence of data on whether the patients refrained from taking these drugs on the day of surgery may have influenced our results.

A case report from 2020 described an elderly patient who underwent elective hip-replacement surgery with spinal anesthesia and subsequently experienced a sudden deterioration in general condition, characterized by tachypnea, decreased oxygen saturation, and neck cyanosis. Noninvasive monitoring revealed hemodynamic instability followed by hypotension and periodic cardiac arrhythmia manifesting with ventricular extrasystoles [20]. While anesthetic agents and antihypertensives are common causes of hemodynamic instability, it can also be a nonspecific symptom of pulmonary thromboembolism, which is yet another reason to investigate all circumstances surrounding intraoperative hemodynamic instability.

Conclusion

Hypotension and bradycardia are frequent complications during both general and spinal anesthesia. General anesthesia is associated with a higher risk of hypotension, making an important consideration when selecting the type of anesthesia, particularly for patients with high perioperative cardiovascular risk. Intraoperative hypotension and bradycardia occur more frequently in patients on chronic antihypertensive therapy, highlighting the need for careful perioperative management of these drugs. Our results did not show a significant difference in the incidence of bradycardia between general and spinal anesthesia. Based on our findings, spinal anesthesia carries a lower risk of intraoperative hypotension. Given the clinical importance of this issue, further studies are needed to determine the incidence of intraoperative hypotension and bradycardia under different types of anesthesia and to more precisely define all associated risk factors.

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Rad je primljen 28. VII 2024.
Recenziran 1. XII 2024.
Prihvaćen za štampu 1. XII 2024.
BIBLID.0025-8105:(2024):LXXVII:7-8:222-227.

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