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ORIGINAL ARTICLE

The effect of different altitude levels on spinal anesthesia in cesarean section surgery: comparison of anesthesia parameters and hemodynamic changes

Efecto de diferentes niveles de altitud sobre la anestesia espinal en la cirugía de cesárea: comparación de los parámetros anestésicos y los cambios hemodinámicos

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Abstract

Objective: *This study aimed to evaluate the impact of varying altitude levels on anesthetic parameters in pregnant women undergoing cesarean sections under neuraxial anesthesia.* **Method:** *Conducted at three different altitudes: sea level (0-10 m, Giresun-Group G), moderate altitude (810 m, Çorum-Group Ç), and high altitude (1725 m, Van-Group V), this study included 98 patients undergoing elective cesarean sections. All were administered the same anesthetic protocol. We assessed anesthetic characteristics and hemodynamic parameters.* **Results:** *Patients at sea level showed a significantly lower upper sensory block limit than those at higher altitudes ($p < 0.01$). The time to reach each Modified Bromage scale level varied, with the shortest at moderate altitudes and longest at high altitudes, particularly noted at the third scale level ($p < 0.01$). Group G had a significantly higher cerebrospinal fluid pH ($p < 0.01$). Although sensory block duration differences were not significant, motor block duration was notably longer at moderate altitude ($p < 0.01$).* **Conclusions:** *Minimal effect on spinal anesthetic block times was observed due to the close proximity of the altitude levels studied. Future research should include higher altitudes and more patients to determine the effect of altitude on anesthetic efficacy and safety.*

Keywords: *Acclimatization. Anesthesia. Pregnancy. Headache. High altitude.*

Resumen

Objetivo: *Evaluar el impacto del nivel de altitud en los parámetros anestésicos en mujeres embarazadas sometidas a cesárea bajo anestesia neuroaxial.* **Método:** *El estudio se realizó a tres altitudes diferentes: nivel del mar (0-10 m, Giresun, grupo G), altitud moderada (810 m, Çorum, grupo Ç) y altitud elevada (1725 m, Van, grupo V). Se incluyeron 98 pacientes sometidas a cesárea electiva. A todas se les administró el mismo protocolo anestésico. Se evaluaron las características anestésicas y los parámetros hemodinámicos.* **Resultados:** *Las pacientes a nivel del mar mostraron un límite superior de bloqueo sensorial significativamente inferior que las situadas a mayor altitud ($p < 0.01$). El tiempo para alcanzar cada nivel de la escala de Bromage modificada varió, siendo el más corto a altitud moderada y el más largo a altitud elevada, especialmente en el tercer nivel de la escala ($p < 0.01$). El grupo G tenía un pH del líquido cefalorraquídeo significativamente más alto ($p < 0.01$). Aunque las diferencias en la duración del bloqueo sensorial no fueron significativas, la duración del bloqueo motor fue notablemente mayor a altitud moderada ($p < 0.01$).* **Conclusiones:** *Se observó un efecto mínimo sobre los tiempos de bloqueo anestésico*

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Date of reception: 11-07-2024
Date of acceptance: 18-10-2024
DOI: 10.24875/CIRU.24000381

Cir Cir. 2026;94(1):21-27
Contents available at PubMed
www.cirugiaycirujanos.com

espinal debido a la proximidad de los niveles de altitud estudiados. Las investigaciones futuras deberían incluir altitudes mayores y más pacientes para determinar el efecto de la altitud en la eficacia y la seguridad de la anestesia.

Palabras clave: *Aclimatación. Anestesia. Embarazo. Cefalea. Gran altitud.*

Introduction

According to the Society of Mountain Medicine, there are three high altitude regions: 1500-3500 m is high altitude, 3500–5500 m is very high altitude, and 5500 m and over is extremely high altitude[1]. More than 100 million people per year visit or travel to highly altitudinous mountain areas for professional, touristic, sports-related, or religious reasons. An estimated 140 million people live at high altitudes (> 2500 m). Individuals living at high and moderately high altitudes undergo respiratory, cardiovascular, and hematological changes to adapt to the conditions[2-5].

As a result of acclimatization, cerebrospinal fluid (CSF) volume increases, and the acid–base balance changes. It has been suggested that these changes are the result of the hyperventilation response to hypoxemia[6]. The increase in CSF volume may contribute to the variabilities noted in motor and sensorial block times during spinal anesthesia. The pH of CSF has been found to be acidotic in highlanders, but the pH returned to normal levels after acclimatization[3-6].

Postdural puncture headache (PDPH) is a possible complication of unintentional dural puncture during epidural anesthesia or intentional dural puncture during spinal anesthesia. The incidence of PDPH after spinal anesthesia depends more on the size of the needle than on the needle's diameter[7]. Although reported in many studies featuring a higher frequency of pregnancy-related PDPH, the effect of high altitude is still unknown. However, we hypothesized that the frequency of PDPH may increase with changes in volume and acid-base balance of CSF.

The onset time and duration of spinal sensory and motor block are affected by factors such as the age, gender, and height of the patient, and the dose and content of the drug[6]. However, whether block time is affected by CSF changes in patients living at high altitudes is still unknown.

In this study, we aimed to investigate the effect of high altitude on CSF pH and anesthetic considerations, such as motor and sensorial onset time and duration after spinal anesthesia, hemodynamic changes during surgery, and the incidence of PDPH in patients who underwent cesarean section surgery.

Method

Study design and population

This prospective controlled study was carried out among pregnant women living in city centers at three different altitudes (Giresun, 0-10 m; Çorum, 810 m; and Van, 1725 m) who underwent elective cesarean sections after the approval of clinical trials (NCT05715476). All procedures involved in the study were explained to the pregnant women, and their oral and written consent was obtained. This study was performed in accordance with the tenets of the Declaration of Helsinki and was reported following the Strengthening the Reporting of Observational Studies in Epidemiology statement[8].

Pregnant women who were aged between 18 and 40 years, were 160-170 cm tall, and had been living for at least one month at the place of the study were included in the study. Pregnant women who had an American Society of Anesthesiologists II status caused by something other than pregnancy, who had contraindicated conditions for spinal anesthesia, such as infection at the needle insertion site and clotting disorders, and who were to be operated on under emergent conditions were excluded from the study. Those living in Giresun were called Group G, those living in Çorum were called Group C, and those living in Van were called Group V. A flowchart regarding the creation of groups is shown in figure 1.

Anesthetic management

Standard monitoring (non-invasive blood pressure, electrocardiogram, pulse oximeter) was applied to the patients taken to the operating table. The same anesthesia protocol was applied to all patients at each altitude. In the sitting position, the spinal range was entered at the L4-L5 dural space using a 25 G Quincke triple needle. A sample of CSF was dropped onto pH indicator paper (Lyphan, Dr. Gerhard Kloz GmbH), which changed color and was evaluated using a scale.

Immediately afterwards, 12 mg of 0.5% hyperbaric bupivacaine was given, and the patient was quickly brought to a 15° left lateral position. The patient's

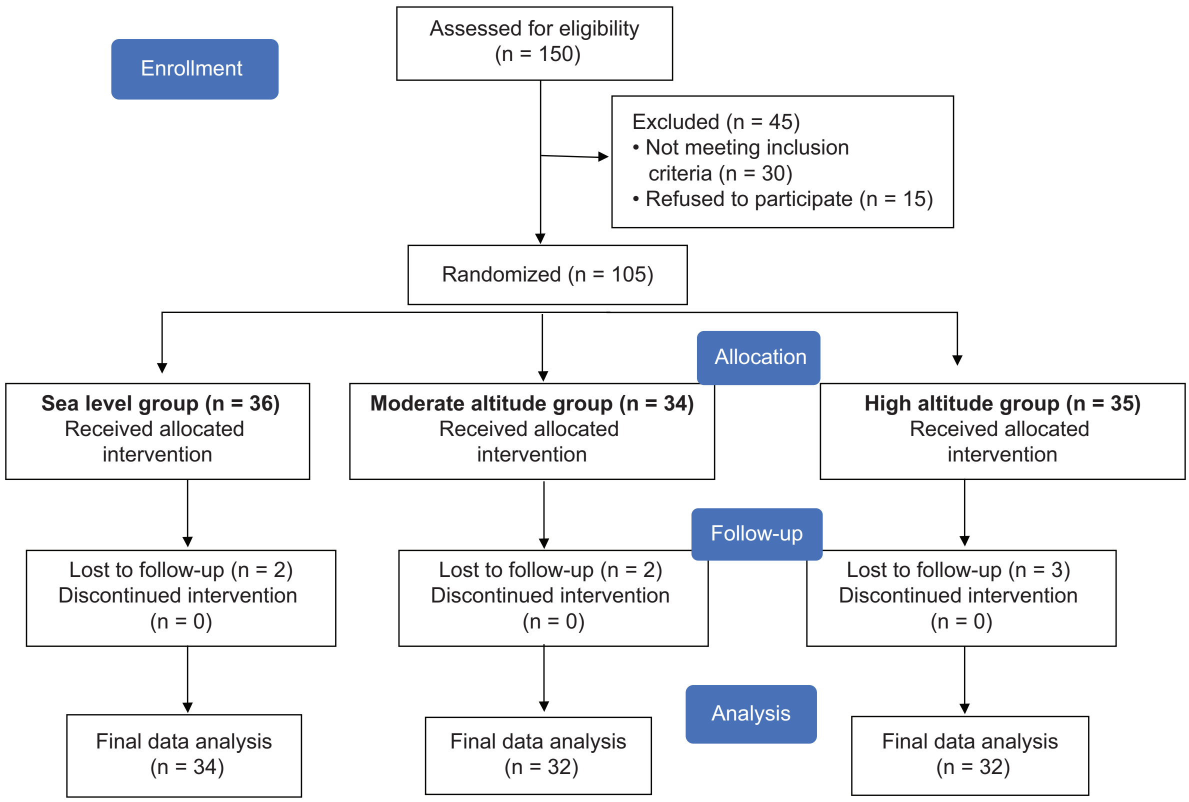

Figure 1. *Consolidated standards of reporting trials flow diagram.*

sensory block level was evaluated using a pinprick test, and the motor block level was evaluated using a Modified Bromage (MB) scale (0: No paralysis, the patient can bring their foot and knee exactly to flexion; 1: They can move only their knee and foot; they can't lift their leg straight; 2: They can bring their knee to flexion; they can move only their foot; 3: They can't move their foot joint or thumb; they have full paralysis).

When the sensory block achieved the thoracic 6 dermatome (T6 dermatome) level, surgery began. If there were not enough blocks within the first 10 minutes after the intrathecal injection, technical failure was accepted, and general anesthesia was performed. Such patients were excluded from the study (Fig. 1; shown in the flow chart). The patients' heart rate, mean arterial pressure, and peripheral oxygen saturation parameters were recorded 8 times. The data were recorded at T1 (basal value), T2 (3rd min), T3 (5th min), T4 (10th min), T5 (15th min), T6 (30th min), T7 (45th min), and T8 (60th min). If a 20% decrease compared to pre-procedure values was noted in blood pressure, 10 mg of ephedrine was administered intravenously. If the heart rate fell below 45 beats/min, 0.5 mg of atropine was administered.

The number of spinal anesthesia applications given and their durations, the time required until T6 dermatome block formation, the time required to reach each level of the MB scale, the highest sensory block level reached, and the presence of anesthesia complications, such as hypotension, bradycardia, were recorded. Patients who were taken to the recovery unit at the end of surgery were transferred to the floor when their sensory block level was below the T6 dermatome and Modified Aldrete score was above 8. Patients' sensory block duration was followed up in the ward (time from local anesthetic injection to S2 dermatome sensation), and motor block duration (time from local anesthetic injection to full motor function improvement) was recorded.

The patients were questioned about PDPH on the first and seventh days post-operation by the researcher via phone call. The patients with PDPH were given 3.000 mL of crystalloid every day and paracetamol 3 times a day. Drinking caffeinated beverages was recommended.

Outcomes

The primary aim of this study is that different altitude levels; to see how it affects CSF pH and whether

Table 1. Demographic characteristics of patients

Patients data	Group G (0-10 m) n = 34	Group C (810 m) n = 32	Group V (1725 m) n = 32	p
Age (year)	31 ± 5	29 ± 6	29 ± 7	0.19
Weight (kg)	79.4 ± 3.9	78.2 ± 5.4	78.2 ± 6.5	0.57
Height (cm)	163 ± 3	164 ± 4	164 ± 4	0.46
BMI (kg/cm^{-2})	29.8 ± 1.8	29.0 ± 1.6	28.9 ± 1.9	0.11

Variables are presented as mean ± standard deviation. A one-way ANOVA test was used. BMI: body mass index.

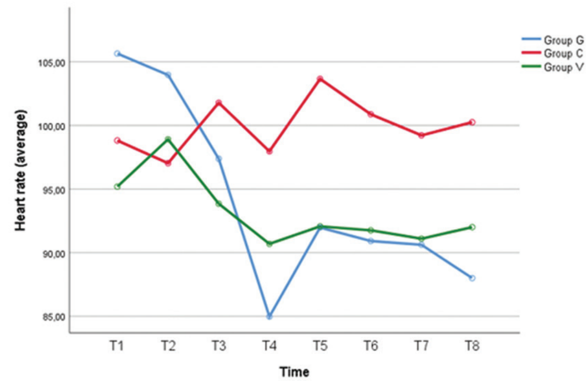

Figure 2. *Variation of heart rate mean values with time.*

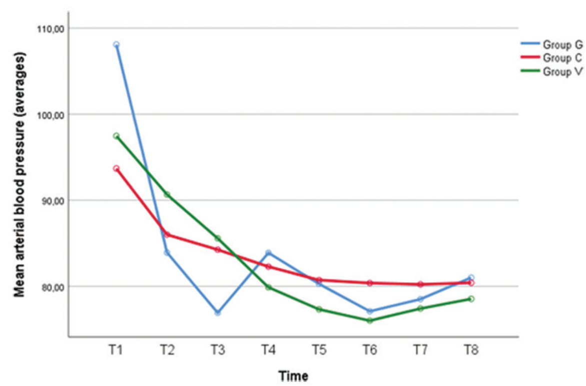

Figure 3. *Variation of mean arterial blood pressure mean values over time.*

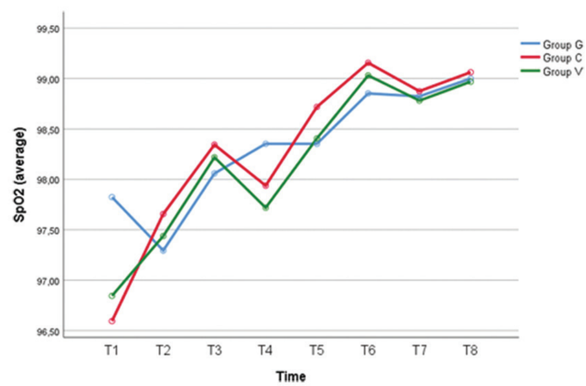

Figure 4. *Variation of SpO_2 mean values with time.*

the local anesthetic drug we use in spinal anesthesia has an effect on motor and sensory block durations. Secondary aims are to see the effects of different altitude levels on PDPH and post-operative nausea and vomiting (PONV).

Statistical analysis

Sample size; the minimum number of patients required to complete our study with 95% confidence level ($\alpha = 0.05$) and 80% power was calculated as 31 for each group, a total of 93. The IBM-Statistical Package for the Social Sciences (IBM-SPSS Inc., Chicago, IL, USA) 22.0 program was used in the analysis of the data obtained in the study. The variables were investigated with "Shapiro-Wilk" test to determine whether or not they are normally distributed. Continuous variables were expressed as mean and standard deviation or (median (25-75th percentile)) according to distribution, and categorical variables were presented as numbers and percentages. In the analysis of continuous variables, the "One-Way analysis of variance (ANOVA) test" was performed in cases where parametric test assumptions were provided. Otherwise, the "Kruskal-Wallis test" was performed. Bonferroni or Games-Howell tests were performed for *post hoc* comparisons. Categorical variables were compared using the Chi-square test. Variance analysis (ANOVA) was used for repetitive measurements between the groups at different times. Statistical significance level was accepted as $p < 0.05$.

Results

The patients were similar in age, gender, weight, height, and body mass index ($p > 0.05$) (Table 1). When the groups were evaluated in terms of heart rate, there were statistically significant differences at all times except T2 and T3 ($p < 0.01$) (Fig. 2). Mean arterial pressure was not significant at all times; however, it was significantly higher at baseline in patients living at sea level than other groups (Fig. 3). Similarly, peripheral oxygen saturation was significantly higher only at the baseline time and T4 in patients living at sea level than other groups (Fig. 4).

Table 2. Characteristics of spinal block by groups

Variables	Group G (0-10 m) n = 34	Group C (810 m) n = 32	Group V (1725 m) n = 32	p
Thoracic-6 dermatome reach time (s)*	160 (120-220)	130 (120-150)	154 (106-174)	0.30
Highest level of sensory block** (%)				
T2	1 (2.9)[a]	0 (0)[a]	2 (6.3)[a]	< 0.01
T3	0 (0)[a]	0 (0)[a]	1 (3.1)[a]	
T4	19 (55.9)[a]	17 (53.1)[a]	23 (71.9)[a]	
T5	13 (38.2)[a]	11 (34.4)[a]	0 (0)[b]	
T6	1 (2.9)[a]	4 (12.5)[a,b]	6 (18.8)[b]	
MB1 reach time (s)*	100 (90-115)	98.5 (90-110)	100 (95.5-147.5)	0.09
MB2 reach time (s)*	155 (120-195)	140 (120-160)	158 (137-197)	0.08
MB3 reach time (s)*	248 (210-300)[a]	210 (195-240)[b]	325 (280-414)[c]	< 0.01
The number of patients required ephedrine** (%)				< 0.01
Yes	14 (41.2)[a]	1 (3.1)[b]	10 (31.3)[a]	
No	20 (58.8)[a]	31 (96.9)[b]	22 (68.8)[a]	
CSF pH*	7.50 (7.50-7.50)[a]	7.40 (7.38-7.40)[b]	7.40 (7.30-7.40)[b]	< 0.01
CSF pH classification** (%)				
Neutral	0 (0)[a]	32 (100)[b]	19 (59.4)[c]	< 0.01
Acidosis	0 (0)[a]	0 (0)[a]	8 (25)[b]	
Alkalosis	34 (100)[a]	0 (0)[b]	5 (15.6)[c]	

*Kruskal-Wallis test.
**Chi-square test.
Each superscript symbol (a, b, c) denotes a subset of source group categories whose column proportions do not differ significantly from each other at the 0.05 level. Variables were presented median (Q1-Q3) or frequency (%), and p < 0.05 was expressed as bold point.
MB: modified bromage scale; CSF: cerebrospinal fluid; T2: postspinal 3rd min; T3: postspinal 5th min; T4: postspinal 10th min; T5: postspinal 15th min; T6: postspinal 30th min.

The times to the onset of sensory blockage to the T6 dermatome were similar among the groups. However, the upper limit of the sensory blockage was significantly lower in those at sea level compared to those in the other groups (p < 0.01). MB scales were evaluated, and although the time required to reach each MB level was significantly shorter in patients living at moderately high altitudes, it was significantly longer in Group V patients (those living at the highest altitude). A statistically significant difference was found only in the third MB scale level (p < 0.01). The frequency of administration of ephedrine was lowest in patients living at moderately high altitudes (p < 0.01) (Table 2).

The pH of the sea level group's CSF was significantly high (p < 0.01). Patients living at sea level had alkalotic CSF, while those at a moderate altitude had pH-neutral CSF. In the high-altitude group, 25% of the patients had acidotic CSF, and 15.6% had alkalotic pH CSF (p < 0.01) (Fig. 5 and Table 2).

Sensory and motor block times in the post-operative period were longer in the moderate altitude group. This was not significant in terms of sensory block, but it was significant in terms of motor block duration (p: 0.05 and p < 0.01; respectively). The incidences of PDPH and PONV were similar between the groups (p: 0.55 and p: 0.15; respectively) (Table 3).

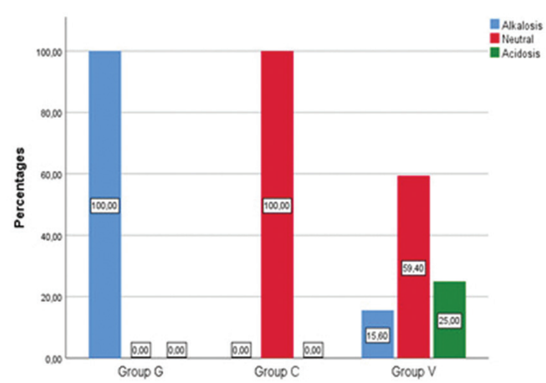

Figure 5. *Cerebrospinal fluid pH category by groups.*

Discussion

According to the literature review, when selecting an anesthesia method, it is best to apply the technique that causes the least effect on ventilation.

Table 3. Post-operative period anesthetic characteristics

Variables	Group G (0-10 m) n = 34	Group C (810 m) n = 32	Group V (1725 m) n = 32	p
Sensory block Time (min)*	151.68 ± 41.80	174.06 ± 47.64	147.47 ± 42.86	0.05
Motor block Time (min)*	163.50 ± 41.21[a]	213.03 ± 49.35[b]	167.81 ± 71.47[a]	< 0.01
PDPH** (%)				
Yes	1 (2.9)	3 (9.4)	2 (6.3)	0.55
No	33 (97.1)	29 (90.6)	30 (93.8)	
PONV** (%)				
Yes	0 (0)	3 (9.4)	1 (3.1)	0.15
No	34 (100)	29 (90.6)	31 (96.9)	

*One-Way ANOVA test.
**Chi-square test.
Variables are shown as mean ± standard deviation or n (%). Each superscript symbol (a, b) denotes a subset of source group categories whose column proportions do not differ significantly from each other at the 0.05 level. Variables were presented as mean ± standard deviation or frequency (%), and p < 0.05 was expressed as bold point.
PDPH: postdural puncture headache; PONV: post-operative nausea and vomiting.

Neuroaxial anesthesia techniques are more appropriate for those living at high altitudes due to the delay in gastric emptying[9]. Few studies are available on the onset time and duration of spinal anesthesia in those living at high altitudes. Aksoy et al.[6] observed that onset time is shorter and the duration is longer in those at sea level than in highlanders. Moreover, there are many factors that affect the intrathecal spread of local anesthetics, such as age, sex, height, and weight. Highlanders experience an increase in CSF, which is the biggest factor that causes variability in spinal sensory anesthesia. In the study, we performed spinal anesthesia on all patients and recorded no differences in the time it took for the block to reach the T6 dermatome. However, motor block duration was significantly longest at the highest altitude (Group V) and shortest at sea level (Group G). The highlanders' delayed motor block start time may be attributed to the increased CSF volume.

Chronic hypoxia causes increased blood pressure in humans living in the highlands[2]. We found that heart rate in patients living at moderately high altitudes (Group C, 810 m) was higher after spinal anesthesia during surgery, except during the second and third minutes. On the other hand, peripheral oxygen saturation and blood pressure were statistically significantly higher at baseline in patients living at sea level (Group G, 0-10 m). This study selected young healthy patients to undergo surgery; thus, advanced hemodynamic monitoring was not required for this assessment.

PDPH is a common complication of cesarean section under spinal anesthesia that causes serious discomfort in patients[10]. Headache is believed to be more prevalent in patients living at high altitudes due to increased cerebral blood flow and/or restriction in cerebral venous outflow[11]. Higher CSF pressure has also been reported to cause more leakage, causing a higher PDPH incidence[12]. There are limited studies in the literature that compare the effects of spinal anesthesia on anesthetic parameters at different altitudes. In one study, PDPH prevalence was found to be higher among patients living at medium-high altitudes than at sea level[6]. In our study, we found no statistically significant difference in PDPH incidence between the groups.

PONV is a common adverse effect of anesthesia and surgery that may cause patient dissatisfaction and lead to prolonged hospital stays and higher costs. One study found no difference in terms of PONV when comparing total intravenous anesthesia and inhalation anesthesia in highlanders[13]. Another suggested that all patients be considered at risk for PONV because of significantly delayed gastric emptying[9]. In our study, the frequency of PONV was similar between the groups.

In one study, the pH of CSF in highlanders was found to be more acidotic as a result of hypoxia, but studies have shown that pH returns to normal as a result of time-dependent acclimatization[14,15]. In our study, following dural puncture, a sample of CSF was dropped onto pH paper and evaluated. We found that CSF is alkalotic at sea level compared to high altitudes.

Limitations

It would have been better to analyze the pH of the CSF in a laboratory instead of using pH meter paper.

The study's patient group was young and healthy; therefore, invasive hemodynamic monitoring was not warranted. If we could have used such monitorization, we could have accessed more precise data on the hemodynamic differences caused by high altitudes.

Conclusions

We theorized that high altitudes would cause a more acidotic cellular environment due to hypoxia and that, accordingly, more local anesthetic agents would be needed. However, when we compared it at different altitudes, we could not reach the results we hypothesized for the block times. Therefore, we think that a comparison should be made with more patients at much higher altitudes.

Funding

The authors declare that they have not received funding.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical considerations

Protection of humans and animals. The authors declare that the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation and with the World Medical Association and the Declaration of Helsinki. The procedures were authorized by the Institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from all patients, and secured approval from the Ethics Committee. SAGER guidelines have been followed as applicable to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing or creation of the content of this manuscript.

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