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EFFECT OF BRACHIAL PLEXUS BLOCK ON THE INCIDENCE OF ARTERIAL HYPOTENSION AND BRADYCARDIA EVENTS DURING SHOULDER ARTHROSCOPY IN ADOLESCENTS

© ***K.S. Trukhin[1], D.V. Zabolotskii[2, 3], V.A. Koriachkin[2], O.V. Kuleshov[1], K.I. Zakharov[1], A.A. Cherednichenko[1], A.Yu. Kulikov[1]***

[1] Clinic of High Medical Technologies named after N.I. Pirogov, Saint Petersburg University, Saint Petersburg, Russia;
[2] Saint Petersburg State Pediatric Medical University, Saint Petersburg, Russia;
[3] H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery, Saint Petersburg, Russia

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Background. The role and significance of the technical aspects of interscalene brachial plexus block in the occurrence of sudden arterial hypotension and bradycardia events during shoulder arthroscopy in a semi-sitting position are ambiguous.
Aim. The study aimed to assess the effect of interscalene brachial plexus block on the incidence of hypotension-bradycardia events during shoulder arthroscopic surgery in adolescents in a semi-sitting position.
Materials and methods. This retrospective analysis of anesthesia protocols included 288 patients who underwent arthroscopic shoulder surgery in a semi-sitting position under the interscalene brachial plexus block. Regional blockades were performed with neurostimulation in Group 1 ($n = 23$), neurostimulation and ultrasound navigation without repositioning the needle in Group 2 ($n = 70$), and neurostimulation and ultrasound navigation with multiple precision repositioning the needle in Group 3 ($n = 195$).
Results. Hypotension-bradycardia events were detected in 26 patients out of 288 (9%). There was a statistically significant difference in the frequency of hypotension-bradycardia in all groups: 10 (43.48%) in Group 1, 15 (21.43%) in Group 2, and 1 (0.51%) in Group 3 ($p = 0.000$). A direct correlation between hypotension-bradycardia episodes and local anesthetic volume ($r = 0.405$; $p < 0.05$), and Horner's syndrome ($r = 0.684$, $p < 0.05$) was found.
Conclusions. Interscalene brachial plexus block with a target delivery of low volume of local anesthetic and dual navigation reduces the risk of hypotension-bradycardia. Horner's syndrome can be considered an early predictor of hypotension-bradycardia events.

Keywords: hypotension-bradycardia events; interscalene brachial plexus block; arthroscopic shoulder surgery; Horner's syndrome.

ВЛИЯНИЕ БЛОКАДЫ ПЛЕЧЕВОГО СПЛЕТЕНИЯ НА ЧАСТОТУ АРТЕРИАЛЬНОЙ ГИПОТОНИИ И БРАДИКАРДИИ ПРИ АРТРОСКОПИИ ПЛЕЧА У ПОДРОСТКОВ

© ***К.С. Трухин[1], Д.В. Заболотский[2, 3], В.А. Корячкин[2], О.В. Кулешов[1], К.И. Захаров[1], А.А. Чередниченко[1], А.Ю. Куликов[1]***

[1] Клиника высоких медицинских технологий имени Н.И. Пирогова, Федеральное государственное бюджетное образовательное учреждение высшего образования «Санкт-Петербургский государственный университет», Санкт-Петербург;
[2] Федеральное государственное бюджетное образовательное учреждение высшего образования «Санкт-Петербургский государственный педиатрический медицинский университет» Министерства здравоохранения Российской Федерации, Санкт-Петербург;
[3] Федеральное государственное бюджетное учреждение «Национальный медицинский исследовательский центр детской травматологии и ортопедии имени Г.И. Турнера» Министерства здравоохранения Российской Федерации, Санкт-Петербург

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Обоснование. При артроскопических операциях на плечевом суставе в положении полусидя не определена роль технических аспектов выполнения межлестничной блокады плечевого сплетения, предрасполагающих к развитию внезапных эпизодов артериальной гипотонии и брадикардии.

Цель — оценить влияние блокады плечевого сплетения межлестничным доступом на развитие эпизодов гипотонии-брадикардии при артроскопических операциях на плечевом суставе в положении полусидя у подростков.

Материалы и методы. Проведен ретроспективный анализ анестезий у 288 пациентов, которым выполняли артроскопические операции на плечевом суставе в положении полусидя в условиях блокады плечевого сплетения межлестничным доступом. В первой группе ($n = 23$) регионарные блокады проводили с помощью нейростимуляции, во второй ($n = 70$) — с помощью нейростимуляции и ультразвуковой навигации без репозиционирования иглы, в третьей ($n = 195$) — с помощью нейростимуляции и ультразвука с многократным прецизионным репозиционированием иглы.

Результаты. Эпизоды гипотонии-брадикардии выявлены у 26 (9 %) пациентов из 288. Отмечено статистически значимое различие по частоте данных осложнений во всех группах: в первой — 10 (43,48 %), во второй — 15 (21,43 %), в третьей — 1 (0,51 %) ($p = 0{,}000$). Обнаружена прямая корреляционная зависимость эпизодов гипотонии-брадикардии от объема местного анестетика ($r = 0{,}405$; $p < 0{,}05$) и от синдрома Горнера ($r = 0{,}684$; $p < 0{,}05$).

Заключение. Блокада плечевого сплетения межлестничным доступом с двойной навигацией и целевой доставкой малых объемов локальных анестетиков снижает риск возникновения эпизодов гипотонии-брадикардии. Ранним предиктором развития гипотонии-брадикардии можно считать синдром Горнера.

Ключевые слова: гипотония-брадикардия; блокада плечевого сплетения межлестничным доступом; артроскопические операции на плечевом суставе; синдром Горнера.

Intraoperative stability of hemodynamic parameters is one of the factors of patient safety during anesthesia. With arthroscopic surgical interventions on the shoulder of a patient who is in a semi-sitting or beach-chair position (raising the head end of the operating table by 45–80° and flexing the hips and knees), under conditions of the interscalene brachial plexus block (IBPB), there is a high probability of developing arterial hypotension-bradycardia (AHB) episodes. The frequency of which, according to the literature, is 13–28% [1–3]. In some cases, AHB can lead to stagnation of the circulation. AHB in a patient in the beach-chair position is considered to be the development of the Bezold–Jarisch reflex due to the redistribution of blood to the lower extremities and stimulation of the receptors of the "empty" left ventricle, vasomotor center, and vagus nerve core [4]. Currently, there is no unambiguous concept of the predisposing factors of this complication [5]. In particular, it is known that AHB syndrome develops with excessive sedation and fentanyl use [6, 7], adrenaline addition in a local anesthetic or irrigation solution [2, 8, 9], and blockade on the right side [6]. In IBPB, many authors used the method of paresthesias or fasciculations in response to neurostimulation and used significant (from 30.0 to 50.0 mL) volumes of local anesthetics [3, 10, 11].

To our knowledge, there is only one study that combined neurostimulation with ultrasound (US) navigation, and the volume of local anesthetics was 13–18 mL [2]. It has been proven that US control during peripheral regional blocks can reduce the volume of local anesthetics [12, 13], but it remains unclear whether lower volumes of anesthetic can reduce the incidence of AHB [5].

Thus, in the available literature, the role and importance of the technical aspects of IBPB implementation in the prevention of AHB are not described.

This study aimed to evaluate the influence of the technique of performing the IBPB on the incidence of AHB during surgeries in the shoulder joint.

Materials and methods

After approval by the local ethics committee of the Saint Petersburg State Pediatric Medical University, a retrospective analysis of the anesthesia protocols was performed for 288 adolescent patients who underwent arthroscopic shoulder surgery from 2011 to 2019.

Criteria for inclusion in the study were surgery under conditions of IBPB in conscious patients or with anxiolysis (no more than three points on the Ramsay scale) and semi-sitting position (beach chair). Exclusion criteria were pathology of the brachiocephalic vessels, cerebral circulation, pacemakers and cardiac conduction system, syncopal condition history, chronic respiratory diseases with respiratory failure of I–II degrees, intraoperative controlled hypotension, and deep drug sedation (four points or more on the Ramsay scale).

The study included 288 patients aged 16–18 years who, after preinfusion (500 mL of crystalloid solution) and premedication (fentanyl at a dose of 50–100 μg [0.5–1 μg/kg], diazepam at a dose of

Table 1

General characteristics of patients

Characteristic	Group 1 (n = 23)	Group 2 (n = 70)	Group 3 (n = 195)	p
Age, years	18 [17; 18]	18 [17; 18]	18 [17; 18]	0.97
Gender, m/f, n, %	16/7 (70/30)	49/21 (70/30)	127/68 (65/34)	0.72
Height, m	1.74 [1.68; 1.78]	1.74 [1.62; 1.8]	1.75 [1.66; 1.8]	0.74
Body weight, kg	64 [59; 70]	64 [56; 74]	65 [59; 73]	0.69
Body mass index	21.6 [20.9; 22.5]	21.6 [20.9; 22.8]	21.8 [21.1; 22.8]	0.67
ASA, I/II, n	19/4	59/11	170/25	0.74

Note. ASA, American Society of Anesthesiologist is the perioperative risk scale of the ASA.

5–10 mg, and ketoprofen at a dose 100 mg intravenously) underwent IBPB. Depending on the method for performing IBPB, the patients were divided into three groups (Table 1).

IBPB was performed in Group 1 using a neurostimulator (Stimuplex HNS12, 1–0.5 mA, 1 Hz, 0.1 ms, B. Braun, Melsungen, Germany) according to the Meier method [14] using 20–30 mL of 0.5% ropivacaine for the brachial plexus block and 10–15 mL of 0.2% ropivacaine for the superficial branches of the cervical plexus block. To determine the total amount of anesthetic, we sensitized the calculated dose of 3 mg/kg ropivacaine.

In Group 2, IBPB was performed under US control (Sonosite M-Turbo, Sonosite, Bothell, USA: 12 MHz linear sensor, transverse scanning at the level of the C_6–C_7 vertebrae with lateral access and long-axis imaging of the needle) and neurostimulation (Stimuplex HNS12, 0.5 mA, 1 Hz, 0.1 ms). The needle was brought to the middle trunk, and having received a neuromuscular response (a contraction of the shoulder biceps), 20–30 mL of 0.5% ropivacaine was injected without further repositioning, controlling its distribution by US navigation to all elements of the brachial plexus subfascially in the interscalene space. Then, a block of the superficial branches of the cervical plexus was performed with 10 mL of 0.2% ropivacaine. To determine the total amount of the anesthetic agent, we focused on US criteria for the solution distribution to all elements of the brachial and cervical plexus but did not exceed the total dose of 3 mg/kg ropivacaine.

In Group 3, IBPB was performed under US navigation (Sonosite M-Turbo: 12 MHz linear sensor, transverse scanning at the level of the C_6–C_7 vertebrae with lateral access and long-axis imaging of the needle) and neurostimulation (Stimuplex HNS12, 0.5 mA, 1 Hz, 0.1 ms) with a selective block of the brachial plexus trunks. This was achieved by repeatedly repositioning the needle and introducing individual boluses of local anesthetic, not exceeding 0.5–1 mL, from each position. The solution was distributed around each trunk of the brachial plexus, which determined the necessary volume of local anesthetic. In total, 7–10 mL of 0.5% ropivacaine for block of the brachial plexus (Fig. 1) and 5–7 mL of 0.2% ropivacaine for the block of the superficial branches of the cervical plexus were used [15].

The quality of the sympathetic component of the block was determined by the perfusion index increase measured by a pulse oximeter on the nail phalanx of finger II of the operated extremity before and 15 min after the block. The quality of the block motor component was evaluated 15 min after the block procedure, in accordance with the possibility of active movements in the deltoid, biceps, and triceps muscles of the shoulder (0 = yes and 1= no). The degree of depth of the sensor block was determined by the pin-prick method in C_4–Th_1

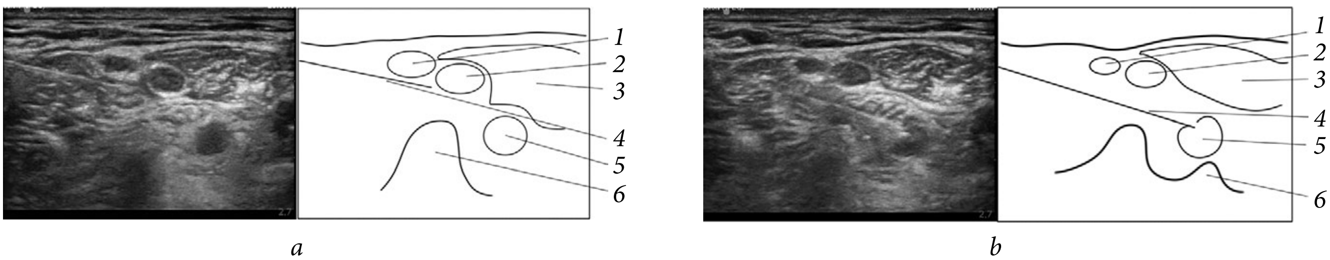

Fig. 1. Block of the upper, middle (*a*), and lower (*b*) trunks of the brachial plexus with lateral access: *1*, the upper trunk of the brachial plexus; *2*, the middle trunk of the brachial plexus; *3*, the anterior scalene muscle; *4*, needle; *5*, the lower trunk of the brachial plexus; *6*, the C_7 vertebra

dermatomes 15 min after the block (0 = complete preservation of sensitivity, 1 = moderate decrease in sensitivity, and 2 = complete anesthesia). The development of Horner's syndrome was recorded (0 = absence and 1 = presence).

After the block, the patient was transferred to the beach-chair position. Oxygen inhalation was provided through the nasal cannula. The level of depth of sedation was evaluated using the Ramsay scale. In emotionally labile patients, propofol was administered intravenously at a rate of 0.5–1 mg/kg per hour to achieve a sedation level of 2–3 points. The used volume of the local anesthetic solution and intraoperative administration of sedating drugs and narcotic analgesics and their dosages were taken into account.

Heart rate (HR) and blood pressure were measured every 5 min using a multifunctional monitor (IntelliVue MP50, Philips, Hamburg, Germany). According to the diagnostic criteria of Song et al. [5], AHB episodes were evaluated as a decrease in HR by at least 30 per minute over a 5-min interval or an HR of less than 50 per minute and/or a decrease in systolic blood pressure by more than 30 mmHg within a 5-min interval or a systolic blood pressure of below 90 mmHg.

Statistical processing was performed using the Statistica 10 software package (StatSoft Inc., Tulsa, USA). The Shapiro–Wilk test determined the normality of distribution. Quantitative variables were presented as the median and interquartile range (25th and 75th percentiles — [Q_1; Q_3]), average values, and confidence intervals. The Kruskal–Wallis test compared the quantitative variables and the χ^2 criterion for categorical variables. The exact Fisher test was used to compare binary variables and with restrictions on the use of the χ^2 criterion. Analysis of variance compared the repeated measurement values. The Spearman's rank correlation coefficient evaluated the relationships between the variables. A p-value of less than 0.05 was considered statistically significant. Post-hoc pairwise comparisons were performed using the Mann–Whitney U test with a significance level of $p < 0.017$.

Results

After transferring to the beach-chair position, AHB occurred after 13.2 ± 3.7 min in 26 (9%) patients. Moreover, AHB developed significantly ($p = 0.000$) less frequently in Group 3 compared with that in Groups 1 and 2. When analyzing the dependence of AHB occurrence on the use of US navigation in the general sample, a weak positive correlation was obtained ($r = 0.354$; $p < 0.05$; Table 2).

There was a statistically significant difference between the groups according to the degree of sensory block in C_8 and Th_1 dermatomes ($p = 0.000$) in the absence of a significant difference in the C_4–C_7 segments. In the general sample, weak correlations between AHB and sensory block were revealed at levels C_8 ($r = 0.365$) and Th_1 ($r = 0.381$; $p < 0.05$), as well as the relationship between AHB and anesthesia method ($r = -0.456$; $p < 0.05$) and the local anesthetic volume ($r = 0.435$; $p < 0.05$; Fig. 2).

There was a weak direct correlation between AHB and perfusion index increase after the block ($r = 0.448$; $p < 0.05$), as well as between the local anesthetic volume and perfusion index ($r = 0.428$; $p < 0.05$).

Table 2

Arterial hypotension-bradycardia and anesthetic characteristics

Indicators	Group 1 (n = 23)	Group 2 (n = 70)	Group 3 (n = 195)	p
Arterial hypotension-bradycardia, n (%)	10 (43.48)	15 (21.43)*	1 (0.51)*†	0.000
IBPB on the right, n (%)	13 (56.52)	46 (65.71)	124 (63.59)	0.73
Volume of local anesthetic, mL	30 [30; 35]	30 [28; 34]	15 [15; 18]*†	0.000
Fentanyl, μg (50/100)	17/6	60/10	172/23	0.164
Initial perfusion index	1.0 [0.8; 1.8]	1 [0.7; 1.6]	0.9 [0.7; 1.5]	0.33
Δ IP after the block	15 [8.3; 18.3]	11 [6.6; 15.8]	8.2 [6.1; 10.3]*†	0.002
Depth of the sensor block:				
with dermatome of C_8 (0/1/2)	0/0/23	0/0/70	85/106/4*†	0.000
with dermatome of Th_1 (0/1/2)	0/0/23	1/0/70*	98/97/0*†	0.000
Duration of the sensor block, h	14 [13; 17]	13 [11; 15]*	12 [10; 14]*†	0.000
Horner's syndrome	17 (73.91)	24 (34.29)*	2 (1.03)*†	0.000

Note. IBPB, interscalene brachial plexus block; Δ PI, increase in perfusion index. *$p < 0.017$ compared with Group 1. †$p < 0.017$ compared with Group 2.

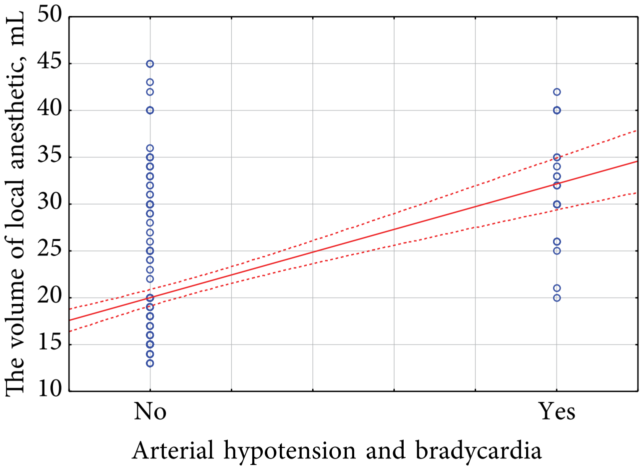

Fig. 2. The correlation between the local anesthetic volume and arterial hypotension and bradycardia episodes ($r = 0.435$; $p < 0.05$; 95% confidence interval)

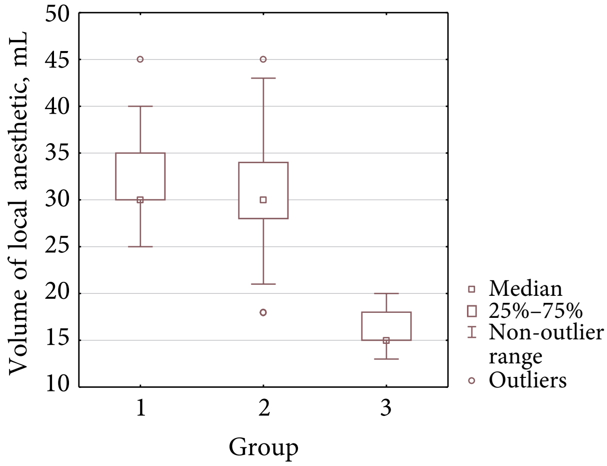

Fig. 3. Volumes of local anesthetic solutions for brachial plexus block ($p < 0.05$)

A statistically significant difference ($p = 0.000$) between the groups in the used volumes of local anesthetic for the brachial plexus block with the maximum volumes in Group 1 was revealed (Fig. 3). In the post-hoc analysis, the differences were statistically significant between Groups 1 and 3 and between Groups 2 and 3 ($p < 0.017$).

There was no significant difference between groups in terms of the depth of sedation ($p = 0.45$), volume of infusion ($p = 0.16$), and use of fentanyl ($p = 0.16$), diazepam ($p = 0.13$), and propofol ($p = 0.077$).

Horner's syndrome was detected in 44 (15.28%) patients, whereas the syndrome development was registered in 18 patients (78.26%) in Group 1, 24 (34.29%) in Group 2, and 2 (1.03%) Group 3 ($p = 0.000$). There was a direct average correlation between AHB and Horner's syndrome ($r = 0.684$; $p < 0.05$). When assessing Horner's syndrome as

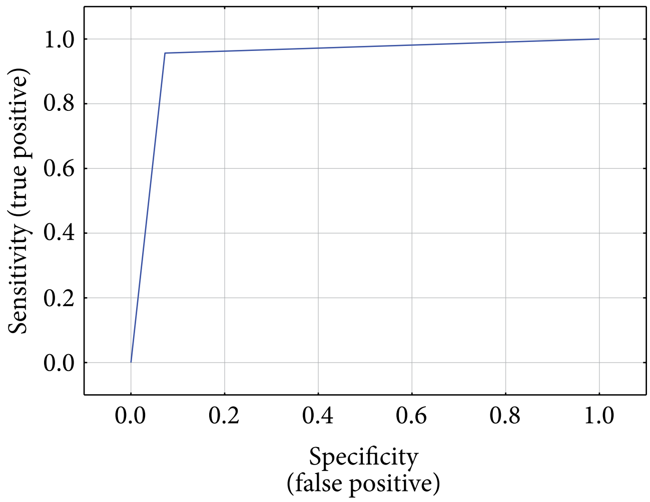

Fig. 4. Receiver operating characteristic analysis of the prognosis of arterial hypotension-bradycardia in the presence of Horner's syndrome

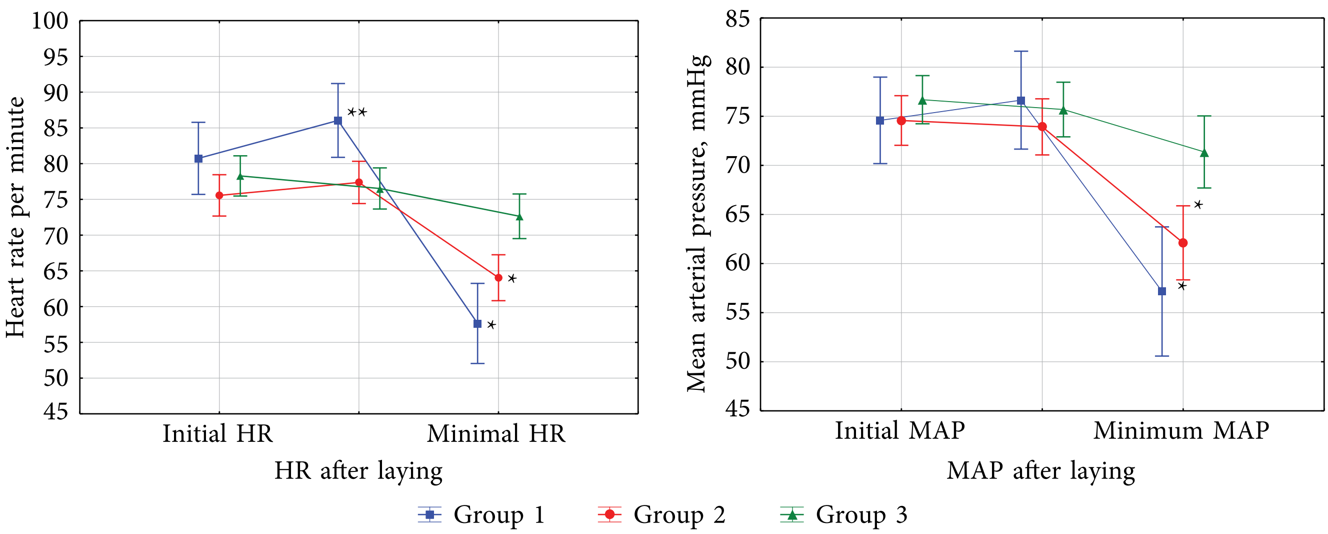

Fig. 5. Analysis of changes in heart rate and mean arterial pressure in the groups (data are presented as mean and 95% confidence interval). * $p < 0.05$ compared with Group 3. ** $p < 0.05$ compared with the baseline. HR, heart rate; MAP, mean arterial pressure

a predictor of AHB development, the sensitivity and specificity were 92.3% and 92.7%, respectively, and the absolute risk of a positive result was 55.8%. In the absence of Horner's syndrome, the probability of AHB was 0.078, and the odds ratio was 153.5 (95% confidence interval 33.7–69.9).

The receiver operating characteristic analysis showed that the area under the curve was 0.925 (Fig. 4), which indicates the excellent prognostic quality of the model for assessing the diagnostic significance of Horner's syndrome in predicting the AHB occurrence.

When assessing the hemodynamic parameters, a significant difference was noted between the minimum HR levels and mean blood pressure in Groups 1 and 2 compared with that in Group 3 ($p < 0.05$). In addition, in Group 1, a statistically significant difference was revealed with a positive trend between the initial HR and the HR after laying in the beach-chair position ($p < 0.05$; Fig. 5).

Discussion

In our study, the frequency of AHB was 9% in the total sample, which is 1.5–3 times less than the literature values of 13% to 28% [3, 5, 8]. In our opinion, this is due to a decrease in the volume of local anesthetics and the use of US navigation and neurostimulation. The frequency of AHB in Group 1 was 43.48%, which is 1.5 times more than in the studies of Liguori et al. [3] and Kim et al. [10]. In Group 3, AHB was registered only in 0.51%.

According to a study by Nallam [11], the use of ondansetron reduced AHB from 22.44% to 6.1%, and a study of Liguori [10] found that the prophylactic administration of beta-adrenoreceptor antagonists (5 mg metoprolol) reduced AHB from 28% to 5% ($p = 0.004$).

One of the triggers of the Bezold–Jarisch reflex is considered to be the initial hypercontractility of the "empty" heart, which can be prevented with beta-adrenoreceptor antagonists [4, 8, 10]. However, the desired effect cannot always be achieved [1]. According to Chierichini et al. [2], the replacement of adrenaline with norepinephrine in irrigation fluid can reduce AHB from 28.4% to 8.3%. In this case, similar volumes of local anesthetics (13.0–18.0 mL) were used in combination with US simulation and neurostimulation. An anesthetic agent was injected into the upper trunk of the brachial plexus or roots of C_5–C_6, achieving diffusion of the anesthetic to all trunks. According to our data, the intraoperative administration of fentanyl did not affect the incidence of AHB. The same results were obtained by Nallam and Dara [11]. We did not note a statistical difference between right-sided and left-sided access to the brachial plexus, unlike the studies of Seo et al. [6] and Simeoforidou et al. [16].

As a result of our analysis, the dependence of the frequency of Horner's syndrome on the volume of local anesthetic was revealed, which confirms the opinion of Sukhani [17] on a direct correlation of the volumes of local anesthetics and the frequency of stellate ganglion block. The literature data on the frequency of Horner's syndrome are ambiguous, and many authors did not reveal any difference when using 20 and 40 mL of local anesthetic for IBPB [18]. In an experiment on cadavers, Feigl et al. [19] found that 30 mL of the stain administered according to the Winnie technique in the interscalene groove spread ventrally and dorsally to the anterior scalene muscle with staining of the sympathetic trunk. Probably, this volume can be considered critical for the development of the sympathetic ganglia block. However, the injection site should also be considered. Thus, Kim et al. [20] revealed that there was no Horner's syndrome when using 20.0 mL of anesthetic injected with interscalene access, but it developed in 2 (8.3%) of 24 patients with 20.0 mL injected with supraclavicular access.

The data are presented that the development of Horner's syndrome does not depend on the use of US navigation, a neurostimulator, or a combination thereof in the case of administration of 20.0 mL of local anesthetic [21], but there is a dependence on age. The authors concluded that the combination of US control and neurostimulation is promising, and because of the accuracy of administration, both the volume of anesthetic and the incidence of Horner's syndrome can be reduced. Our data in Group 3, using dual navigation and targeted selective delivery of local anesthetic, confirm these assumptions.

A further decrease in the volume of local anesthetic is considered inappropriate because of a decrease in the block duration [22]. In our work, we did not reveal a correlation between Horner's syndrome and age ($r = 0.017$; $p < 0.05$). The direct relationship of Horner's syndrome with AHB ($r = 0.684$; $p < 0.05$) confirms the hypothesis of Seo et al. [6] and Song et al. [5] that stellate ganglion block can lead to AHB.

Conclusion

The implementation of the IBPB under US navigation and the use of neurostimulation can reduce the volume of local anesthetic, ensuring its selective targeted delivery, and reduce the incidence of AHB. Horner's syndrome should be considered an early predictor of the development of AHB episodes.

Additional information

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Conflict of interests. The authors declare no obvious or potential conflicts of interest related to the publication of this article.

Ethical statement. The study was conducted in accordance with the ethical standards of the Helsinki Declaration of the World Medical Association as amended by the Ministry of Health of Russia and approved by the ethics committee of the Saint Petersburg State Pediatric Medical University (protocol No. 12/1 of 12/10/2018). Patient representatives signed an informed consent to participate in the study and published data without identification.

Author contributions

K.S. Trukhin developed the study methodology and design, wrote all sections of the article, and performed data collection and analysis and the literature analysis.

D.V. Zabolotsky developed the study methodology and design and performed stage editing of the article.

V.A. Koryachkin performed stage editing of the article.

O.V. Kuleshov developed the study methodology and design.

K.I. Zakharov, A.A. Cherednichenko, and *A.Yu. Kulikov* collected and analyzed the data.

All authors made a significant contribution to the research and preparation of the article and read and approved the final version before publication.

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Information about the authors

Konstantin S. Trukhin* — MD, anesthesiologist and intensive care specialist, Clinic of High Medical Technologies named after N.I. Pirogov, Saint Petersburg University, Saint Petersburg, Russia. https://orcid.org/0000-0002-5410-0467. E-mail: k_truhin_dok@mail.ru.

Константин Сергеевич Трухин* — врач — анестезиолог-реаниматолог отделения анестезиологии и реанимации, Клиника высоких медицинских технологий им. Н.И. Пирогова, ФГБОУ ВО «Санкт-Петербургский государственный университет», Санкт-Петербург. https://orcid.org/0000-0002-5410-0467. E-mail: k_truhin_dok@mail.ru.

Dmitrii V. Zabolotskii — MD, PhD, D.Sc., Professor, Head of the Chair of Anesthesiology, Intensive Care and Emergency Pediatrics, Saint Petersburg State Pediatric Medical University; Senior Research Associate of the Department of Spine Pathology and Neurosurgery, H. Turner National Medical Research Center for Children's Orthopedics and Trauma Surgery, Saint Petersburg, Russia. https://orcid.org/0000-0002-6127-0798.

Дмитрий Владиславович Заболотский — д-р мед. наук, профессор, заведующий кафедрой анестезиологии, реаниматологии и неотложной педиатрии им. В.И. Гордеева, ФГБОУ ВО СПбГПМУ Минздрава России; старший научный сотрудник отделения патологии позвоночника и нейрохирургии, ФГБУ «НМИЦ детской травматологии и ортопедии имени Г.И. Турнера» Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-6127-0798.

Viktor A. Koriachkin — MD, PhD, D.Sc., Professor, Department of Anesthesiology, Intensive Care and Emergency Pediatrics, Saint Petersburg State Pediatric Medical University, Saint Petersburg, Russia. https://orcid.org/0000-0002-3400-8989.

Виктор Анатольевич Корячкин — д-р мед. наук, профессор кафедры анестезиологии, реаниматологии и неотложной педиатрии им. В.И. Гордеева, ФГБОУ ВО СПбГПМУ Минздрава России, Санкт-Петербург. https://orcid.org/0000-0002-3400-8989.

Oleg V. Kuleshov — MD, PhD, Head of the Anesthesiology and Intensive Care Department, Clinic of High Medical Technologies named after N.I. Pirogov, Saint Petersburg University; Associate Professor of the Department of Anesthesiology and Reanimatology, North-Western State Medical University named after I.I. Mechnikov, Saint Petersburg, Russia. https://orcid.org/0000-0001-5177-2527.

Олег Владимирович Кулешов — канд. мед. наук, заведующий отделением анестезиологии и реанимации, Клиника высоких медицинских технологий им. Н.И. Пирогова, ФГБОУ ВО «Санкт-Петербургский государственный университет»; доцент кафедры анестезиологии и реаниматологии, ФГБОУ ВО «СЗГМУ им. И.И. Мечникова», Санкт-Петербург. https://orcid.org/0000-0001-5177-2527.

Kirill I. Zakharov — MD, Orthopedic and Trauma Surgeon of the Traumatology Department, Clinic of High Medical Technologies named after N.I. Pirogov, Saint Petersburg University, Saint Petersburg, Russia. https://orcid.org/0000-0003-1440-4308.

Кирилл Игоревич Захаров — врач-травматолог отделения травматологии, Клиника высоких медицинских технологий им. Н.И. Пирогова, ФГБОУ ВО «Санкт-Петербургский государственный университет», Санкт-Петербург. https://orcid.org/0000-0003-1440-4308.

Andrei A. Cherednichenko — MD, anesthesiologist and intensive care specialist, Clinic of High Medical Technologies named after N.I. Pirogov, Saint Petersburg University, Saint Petersburg, Russia. https://orcid.org/0000-0002-4290-4206.

Андрей Александрович Чередниченко — врач — анестезиолог-реаниматолог отделения анестезиологии и реанимации, Клиника высоких медицинских технологий им. Н.И. Пирогова, ФГБОУ ВО «Санкт-Петербургский государственный университет», Санкт-Петербург. https://orcid.org/0000-0002-4290-4206.

Aleksei Yu. Kulikov — MD, PhD, anesthesiologist and intensive care specialist, Clinic of High Medical Technologies named after N.I. Pirogov, Saint Petersburg University, Saint Petersburg, Russia. https://orcid.org/0000-0003-0130-253X.

Алексей Юрьевич Куликов — канд. мед. наук, врач — анестезиолог-реаниматолог отделения анестезиологии и реанимации, Клиника высоких медицинских технологий им. Н.И. Пирогова, ФГБОУ ВО «Санкт-Петербургский государственный университет», Санкт-Петербург. https://orcid.org/0000-0003-0130-253X.