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

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Received: 25.10.2019 Revised: 18.02.2020 Accepted: 10.03.2020

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

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Поступила: 25.10.2019 Одобrena: 18.02.2020 Принята: 10.03.2020

Pediatric Traumatology, Orthopaedics and Reconstructive Surgery. Volume 8. Issue 1. 2020
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...
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 C6–C7 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 C4–Th1

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

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

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 C7 vertebra
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 $\chi^2$ criterion for categorical variables.

### Results

After transferring to the beach-chair position, AHB occurred after $13.2 \pm 3.7$ 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

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

Note. IBPB, interscalene brachial plexus block; $\Delta$ PI, increase in perfusion index. *$p < 0.017$ compared with Group 1. †$p < 0.017$ compared with Group 2.
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
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-adrenoceptor 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-adrenoceptor 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 C5–C6, 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

Source of funding. The study was not financially supported.

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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