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Modern possibilities of upper extremity regional anesthesia

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Today, regional anesthesia is widely used during surgical interventions in orthopedic surgery. Blockades of individual nerves and plexuses are used. Objective. To introduce readers: surgeons, orthopedists-traumatologists with the possibilities of regional anesthesia like an adequate method of analgesia during upper limb interventions. Methods. Relevant literature from PubMed, Scopus, Google Scholar databases and own experience of regional anesthesia were analyzed. The results. The work describes the effect of regional anesthesia on the nervous, respiratory, cardiovascular and coagulation systems. Information about blocks of peripheral nerves of the upper extremities: interscalene, supraclavicular, subclavian, axillary. Their advantages and disadvantages were analyzed. Interscalene block is not recommended for patients with severe lung disease due to the risk of respiratory failure. Complications of this analgesia include: phrenic nerve block (up to 100 %), sympathetic chain block and Horner's syndrome. Also, possible accidental injection into the vertebral artery. Indications for the supraclavicular block are operations on the hand, forearm, elbow and shoulder. Complications — phrenic nerve block (17–50 %), recurrent laryngeal blockade (22 %), pneumothorax (0.6–6.1 %). When planning anesthesia, the accompanying pathology of the patient and his general condition should be taken into account. Particular care is required when the patient is taking anticoagulants. Risk of bleeding and thrombosis should be carefully assessed. Special attention should be paid to the toxicity of local anesthetics and ways to eliminate it. Conclusions. Regional anesthesia can be used in the pre-, intra- and postoperative periods. Sometimes it's the only method that permit surgical intervention. It is necessary to understand all the advantages and limitations to ensure high quality of patient care.

Під час проведення оперативних утручань в ортопедичної хірургії сьогодні широко застосовують регіонарну анестезію. Використовують як блокади окремих нервів, так і сплетінь. Мета. Ознайомити коло читачів-хірургів, ортопедів-травматологів із можливостями регіонарної анестезії для адекватного вибору методу знеболювання в разі хірургічних утручань на верхній кінцівці. Методи. Проаналізовано релевантну літературу з баз PubMed, Scopus, Google Scholar та власний досвід використання регіонарної анестезії. Результати. У роботі охарактеризовано вплив регіонарної анестезії на нервову, дихальну, серцево-судинну та систему згортання крові. Наведено інформацію про блоки периферичних нервів верхніх кінцівок: міждрабинчастого, надключичного, підключичного, пахвового. Проаналізовано їхні переваги та недоліки. Виконання міждрабинчастого регіонарного блока не рекомендовано пацієнтам із тяжкими захворюваннями легень через ризик розвитку дихальної недостатності. Також до ускладнень цієї аналгезії належать: блок діафрагмального нерва (до 100 %), симпатичного вегетативного ланцюжка та синдром Горнера; можлива ненавмисна ін'єкція в хребетну артерію. Показання до надключичного виду анестезії — операції на кисті, передпліччі, зоні ліктьового суглоба та плеча. Його ускладнення — блок діафрагмального нерва (17–50 %), рецидивна блокада гортанного (22 %), пневмоторакс (0,6–6,1 %). Під час планування анестезії слід ураховувати супутню патологію хворого, його загальний стан. Особливої уваги вимагають ситуації, коли пацієнт приймає антикоагулянтні засоби. У цих випадках ретельно зважують ризики виникнення тромбозу та кровотечі. Зауважено на такому ускладненні регіонарної анестезії, як системна інтоксикація місцевими анестетиками та шляхах її подолання. Висновки. Регіонарна анестезія може бути застосована в до-, інтра- та післяопераційному періодах, інколи є єдиним методом, що дозволяє провести хірургічне втручання. Розуміння її можливостей і обмежень — важлива складова якісної допомоги пацієнтам. Ключові слова. Регіонарна анестезія, блокада периферичних нервів, ускладнення регіонарної анестезії.

Key words. Regional anesthesia, peripheral nerves block, complications of regional anesthesia

Introduction

Owing to new materials, technologies and methods, surgical orthopedics has become one of the most rapidly developing specialties. With 22.3 million orthopedic interventions being performed in the world in 2017, 28.3 million are expected this year, i. e., an annual quantitative increase of 4.9 % [1]. The effect of local anesthesia was first described by Vasyl Kostyantynovich von Anrep during his internship in Würzburg (1879). He was the first in the world to experimentally substantiate the local anesthetic effect of cocaine, dosage and method of its use. The results of these studies by von Anrep were published in the German journal Archiv fur Physiologie (1879). In 1884, he specified recommendations for the use of cocaine in the case of inflammatory diseases based on his own five-year clinical experience in the article «Cocaine as a local anesthetic» (according to [2]).

In recent years, regional anesthesia has become the most common method of pain relief during many orthopedic interventions. Its essence consists in the administration of local anesthetic solution to interrupt the transmission of the signal by nerve fibers. This way provides the sensory and motor components of the block. Although blocks are performed by anesthesiologists, surgeons wishing to improve the quality of treatment need to understand their clinical effects.

The purpose of the study: to provide surgeons, orthopedists and traumatologists with the data on possibilities of regional anesthesia for an adequate choice of the method of analgesia in the case of surgical interventions on the upper limb.

Material and methods

Relevant literature from PubMed, Scopus, Google Scholar databases and own experience of using regional anesthesia were analyzed.

Results and their discussion

Peripheral nerve block is also called conduction anesthesia (CA). A local anesthetic injected into the area of a nerve or plexus leads to sensory and motor blockade of the corresponding areas of the body. CA can be used for pain relief both during surgery and in the postoperative period. Most often, CA is performed by a single injection of anesthetic; the use of catheters for prolonged analgesia is significantly less common. This is due to the high incidence of catheter migration due to the impossibility of reliably fixing its tip perineurally.

Today, the standard has become the use of at least one method of atraumatic nerve search: ultrasound (US) navigation or electrical stimulation. The combination of these methods significantly increases the quality of CA.

Interventions on the upper extremity most often require interscalene, supraclavicular, subclavicular or axillary blocks.

Preparing the patient for regional anesthesia

The decision to perform regional anesthesia is made jointly by the anesthesiologist, the surgeon and the patient. When planning anesthesia, attention should be paid to risk factors related to nervous, pulmonary, cardiovascular disorder and parameters of the coagulation system should be taken into account. Some features can significantly complicate the implementation of anesthesia. For example, obesity is associated with an increased risk of unsuccessful paravertebral blocks [3]. A local or systemic infectious process can interfere with regional anesthesia. Vascularization and the risk of compression due to the formation of a hematoma in adjacent tissues should be assessed in patients who are scheduled to perform CA of superficial peripheral nerves while taking anticoagulants or antiplatelet drugs.

Let us consider the effect of regional anesthesia on body systems. First of all, when planning such analgesia, it is necessary to find out the state of the nervous system and the possibility of previous damage to the nervous structures in the area of intervention.

Respiratory system. Regional anesthesia makes it possible to exclude the risks associated with concomitant respiratory diseases. However, if sedation is required, these risks remain in full. Besides, interscalene or supraclavicular block can result in the development of anesthesia of the phrenic nerve, which is dangerous in patients with asthma or chronic obstructive pulmonary disease, so it is necessary, if possible, to render axillary block [4], use ultrasound navigation and enter a minimum volume anesthetic

As for the *cardiovascular system*, due to the use of regional anesthesia, it is possible to achieve a reduction in the incidence of cardiac postoperative complications associated with the corresponding existing comorbidities [5]. But it is very important to pay attention to the choice of local anesthetic and use the least cardiotoxic drug.

Coagulation system. Information about blood coagulation disorders, as well as the patient's taking of anticoagulant or antiplatelet drugs lead to an increased risk of hemorrhagic complications after regional anesthesia and require thorough history taking, including data on the drug therapy used. Despite the greatest risks under the conditions of using neuraxial anesthesia, it is necessary to consistently

follow the perioperative recommendations for regional anesthesia with anticoagulant therapy [6].

Upper limb block

The success of CA of the upper extremity depends on understanding the anatomy of the brachial plexus (see Figure). It provides muscular and skin innervation of the upper limb. The brachial plexus consists of ventral nerve roots (branches) of 5 spinal nerves (C_V–Th_I), which give rise to trunks, divisions, cords and terminal branches. Nerve roots merge, forming the upper, middle and lower trunks. They divide, forming 6 divisions that merge into 3 branches: lateral, posterior and medial cords. The nerves that innervate most of the upper limb are terminal branches of the three cords. The skin part of the shoulder and forearm is supplemented by nerves that are not part of the brachial plexus [7]. The upper part of the shoulder receives sensory innervation from the superficial cervical plexus (C_{III}–C_{IV}) through the supraclavicular nerve. 70% of the sensory innervation of the shoulder originates from the upper trunk through the suprascapular nerve, and the greater contribution belongs to C_V and C_{VI} nerve roots [8]. The axilla is innervated by the Th_{II} root.

The brachial plexus is blocked at four different levels: interscalene block for the roots-trunks, supraclavicular for the trunks-departments, subclavicular for ligaments and axillary for the terminal branches. Summary information about blocks of peripheral nerves of the upper limbs is given in Table. 1.

The interscalene block is performed only at the level of the trunks of the brachial plexus near their origin. Anesthesia extends from C_V to C_{VIII}, affecting

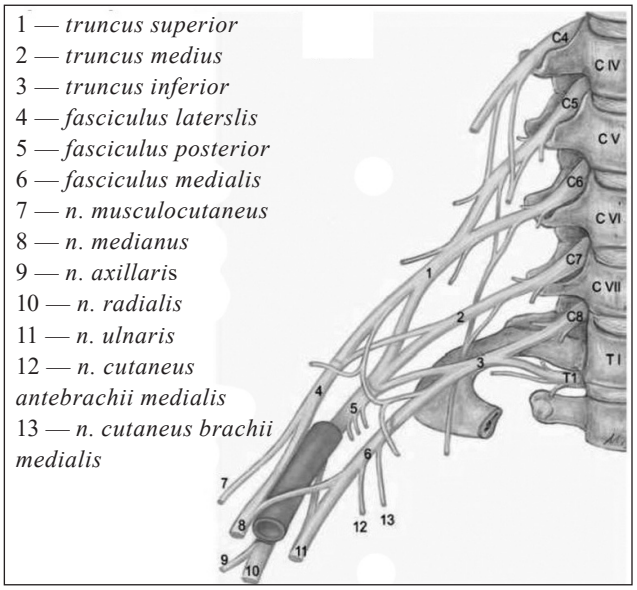

Figure. Anatomy of the brachial plexus (adapted from [9])

the supraclavicular branches of the cervical plexus C_{III} and C_{IV}, which innervate the skin over the acromion and clavicle. The area of anesthesia is the shoulder, the proximal part of the humerus, the distal part of the clavicle. Without special access to the lower trunk of the brachial plexus, at the level of S_{VIII}–Th_I, anesthesia does not extend to the level of the elbow joint and beyond [8].

Access to the brachial plexus in the case of an interscalene block is performed between the anterior and middle scalene muscles, lateral to the carotid artery and internal jugular vein, directly above the clavicle.

This block has certain features and complications: with a frequency close to 100 %, there is a block of the phrenic nerve [10, 11], a little less often it results in a block of the sympathetic autonomic chain and Horner's syndrome. Inadvertent injection into the vertebral artery is also possible [12]. Rare complications include pneumothorax, epidural or intrathecal injection of anesthetic, which can lead to total spinal anesthesia, damage to the spinal cord and spinal scapular or long thoracic nerve. Due to phrenic nerve block, this regional block is not recommended for patients with severe lung disease because of the risk of respiratory failure. Therefore, the use of a two-sided interscalene block is unacceptable.

The supraclavicular block affects the brachial plexus above the clavicle at the level of trunks and divisions, including segments C_V–C_{VII} from the more superficial and lateral branches that innervate the shoulder, the lateral part of the arm and forearm, as well as the deeper and medial branches of C_{VIII} and Th_I. To obtain high-quality anesthesia of the upper limb, the anesthetic should be injected into both areas [8]. Access is performed between the anterior and middle scalene muscles at the level of the first rib, where the subclavicular artery passes behind the middle of the clavicle.

If performed correctly, intense and long-lasting anesthesia of the upper limb develops, starting from the shoulder, which is determined by the close location of all the trunks and departments of the brachial plexus in this place. Indications for this type of anesthesia are operations on the hand, forearm, elbow joint, and shoulder.

When performing a supraclavicular injection, the frequency of a phrenic nerve block is slightly lower than for a supraclavicular one, and occurs in 17–50 %, and recurrent laryngeal nerve block, which leads to hoarseness, occurs in 22 % [13]. Complications of supraclavicular block include pneumothorax (0.6–6.1 %), since the apex of the pleura is in close proximity to

Table 1

Blocks of peripheral nerves of the upper limb

Block	Clinical application	Blocked nerve	Anatomical landmark	Advantage	Disadvantage	Complication
Interscalene	Operations on the humerus, its proximal and distal part of the clavicle	Brachial plexus C_V–C_{VII}. Cervical plexus. Supraclavicular nerve (C_{III} and C_{IV})	Anesthetic is injected between the anterior and middle scalene muscles lateral to the carotid artery and internal jugular vein	Easy to perform. Patient-friendly	Hemidiaphragmatic paralysis leading to respiratory failure in patients with severe COPD. Insufficient for operations on elbows, forearms or hands	Diaphragmatic paralysis nerve (100 %). Horner's syndrome. Hoarseness
Supraclavicular	Operations on the elbow joint, forearm and hand. Extension into the interscalene space may involve the shoulder	C_V–T_I	Anesthetic is injected above the clavicle between the scalene anterior and middle scalene muscles at the level of the first rib where the subclavicular artery crosses above it	Rapid onset. Easier to perform. Convenient for the patient	Higher incidence of pneumothorax	Pneumothorax. Paralysis of the phrenic nerve. Hoarseness of voice
Subclavicular	Operations on the elbow joint, forearm and hand	C_V–T_I	Anesthetic is administered around the axillary artery below the clavicle, more medial to the coracoid process	Good choice for catheter placement	Deep block to perform. Greater discomfort during performance	Pneumothorax (rarely)
Axillary	Operations on the elbow joint, forearm and hand without applying a tourniquet to the shoulder	Median nerve, ulnar nerve, radial nerve and musculocutaneous nerve	Anesthetic is injected around the axillary artery in the medial part of the proximal part of the arm	Easy to perform. Low frequency of complications	Rarely affects the musculocutaneous nerve. Requires abduction of the arm	Formation of a hematoma. Intravascular injection

Note. COPD is a chronic obstructive pulmonary disease

the area of the procedure, but under the conditions of using ultrasound navigation, this undesirable event becomes extremely rare, up to 0 % [14].

The subclavicular block is performed at the level of the ligaments before the branching of the axillary and musculocutaneous nerves. In the upper extremity, the same areas are anesthetized as for the supraclavicular block: the distal part of the shoulder, elbow, forearm, and hand.

Access to the nerves located near the axillary artery is best done with ultrasound navigation, surrounding the artery and all three bundles of the brachial plexus with anesthetic in the form of the letter U. Pneumothorax is a rare complication even in the absence of navigation (0.7 %) [15].

The axillary block is performed at the level of the branches of the brachial plexus: median, ulnar, radial, and musculocutaneous nerves. Anesthesia extends distally beyond the lower third of the shoulder, to the elbow of the forearm and the hand. The name of this block is determined by access and it should be remembered that the axillary nerve is not affected by the axillary block. To perform this block in a patient who is lying on his back, the arm is abducted at the shoulder joint to 90° without rotation. The median, ulnar, and radial nerves surround the axillary artery and lie between the biceps and coracobrachial muscles, located anteriorly, and the tendons of the teres major and latissimus dorsi, located medially and posteriorly. The musculocutaneous nerve passes between the fascial sheets of the coracobrachial and biceps muscles.

An axillary block can be complicated by hematoma formation and intravascular injection of anesthetic because of its close proximity to the axillary artery and vein. Arm abduction may be difficult in certain upper extremity injuries, and in such cases another approach to the nerves should be used.

Complications of regional anesthesia

Systemic toxicity of local anesthetics (STLA) is a potentially life-threatening complication that can result from inadvertent intravascular injection of a local anesthetic or slow absorption of an inadequately high dose of perineurally administered local anesthetic. The American Society of Regional Anesthesia (ASRA) regularly updates guidelines for the management of patients with STLA, with the latest publication in 2021 [16].

Presentation and rate of development of STLA are extremely variable. Symptoms may appear immediately, but full development occurs within 30 minutes or more. The progression of symptoms is continuous — from neurotoxicity at low blood concentrations to cardiotoxicity at high concentrations.

Early clinical signs of neurotoxicity are subjective and include dizziness, drowsiness, numbness around the mouth, and tinnitus. If contact with the patient is impossible or difficult, the patient is sedated or under general anesthesia, these initial signs will almost certainly be missed. The next symptom with an increase in the concentration of the anesthetic in the plasma will be muscle twitching and tremors, and then generalized tonic-clonic convulsions develop. Finally, there is a generalized depression of the central nervous system, which leads to a decrease in the level of consciousness and coma [17].

Cardiotoxic effect develops in two stages. At first, arterial hypertension and tachycardia occur due to the activation of the sympathetic nervous system. This is followed by myocardial depression, triggering ventricular arrhythmias, conduction disturbances, contractile dysfunction, and cardiovascular collapse. Inhibition of potential-dependent sodium channels of the myocardium by local anesthetics significantly increases the PR interval and the duration of the QRS complex, and also leads to changes in the T wave [18].

Treatment of STLA involves early intravenous administration of a lipid emulsion, which extracts the local lipophilic anesthetic from plasma and tissues. In addition, intralipid improves cardiac output by directly affecting myocardial tissue [19]. Intralipid should be administered as a body weight-dependent bolus with subsequent infusion. If the patient is unstable, the bolus should be repeated and the infusion rate doubled. After achieving stable hemodynamics, intralipid infusion lasts at least 15 min [20]. Convulsions should be eliminated by intravenous benzodiazepines or small doses of propofol. In the event of cardiovascular collapse, an intravenous infusion of epinephrine should be started, and if boluses are required, they should not exceed 1 μg/kg to rule out ventricular fibrillation or tachycardia. A dosage of 1 mg administered in cardiopulmonary resuscitation leads to poor long-term results due to the increased risk of arrhythmogenicity. Brief information about the presentation and treatment of STLA is presented in Table 2.

Low muscle mass, female gender, and concomitant cardiac, hepatic, and metabolic diseases are considered risk factors for the development of STLA [21]. According to the ASRA recommendations, STLA can be prevented by using ultrasound navigation, aspiration before each injection of anesthetic, using the lowest effective dose, adding epinephrine for the administration of potentially toxic doses of local anesthetic [22]. Another argument in favor of adding epinephrine to a local anesthetic is its ability to increase heart rate when administered intravascularly. An anesthetist's attempt to block a patient's multiple nerves/plexuses, such as the adductor and popliteal, also increases the risk of STLA. The addition of local anesthetic by surgeons in the area of the operative field should be extremely careful. Given the danger of STLA for patients, it is advisable to conduct a regular review of care protocols for this condition. Staff training in the diagnosis and treatment of STMLA, as well as the availability of therapeutic agents, reduce the patient's risk of facing serious consequences of this complication [23].

An experienced anesthesiologist is not immune to inadequate block. Because of this, the target area will remain sensitive, the patient will have pain, the time of operations will increase, and there will be repeated attempts of blocks and/or the transition to general anesthesia. Of course, the experience of the anesthesiologist is important during anesthesia [22]. The next most important aspect of CA administration with electrical stimulation is the strength of the current when searching for the nerve: the stronger the stimulation, the greater the distance of the needle from the nerve a motor response occurs, which in turn leads to the injection of anesthetic outside the neurovascular bundle. Proper positioning of the patient prior to performing a block using rollers must be used to obtain a quality block. The quality of anesthesia is affected by body weight: in increased body mass index the possibility of inadequate anesthesia also rises, which is associated with the difficulty of determining anatomical landmarks. Also, patients with a high anesthetic risk (ASA IV) have a higher frequency of ineffective block [3].

Unfortunately, attempts to catheterize peripheral nerve structures often end in failure. For example, brachial plexus catheterization can be ineffective in

Table 2

Presentation and treatment of systemic intoxication with local anesthetics

Systemic toxicity of local anesthetics (STLA)
Presentation:
1. Dizziness, drowsiness, tinnitus, numbness around the mouth;
2. Muscle twitches and tremors;
3. Convulsions;
4. Depression of the central nervous system, coma;
5. Hypertension, tachycardia;
6. Myocardial depression, ventricular arrhythmias, conduction delay;
7. Electrocardiogram changes: prolongation of PR, QRS; TL wave changes;
8. Cardiovascular collapse
STLA therapy:
1. Call for help;
2. . Provide adequate ventilation, inhalation of 100 % O_2;
3. Start early introduction of lipid emulsion:
a) the patient's weight is less than 70 kg: bolus 1.5 ml/kg for 2–3 min, infusion 0.25 ml/kg/min. Repeat the bolus or double the infusion rate if the patient's condition remains unstable
b) patient weight over 70 kg: bolus of approximately 100 ml for 2–3 minutes, infusion of approximately 250 ml for 15–20 minutes. Repeat the bolus or double the infusion rate if the patient's condition remains unstable
c) if the patient is stable, continue the introduction of lipid emulsion for 15 minutes or more after stabilization of hemodynamics. The maximum dose of lipids is 10 ml/kg
4. Convulsions:
a) maintenance of airway patency;
b) benzodiazepines;
c) if necessary, low doses of propofol
5. Arrhythmia or cardiovascular instability:
a) epinephrine in a dose lower than for cardiopulmonary resuscitation, starting at 1 μg/kg or less;
b) avoid local anesthetics, beta blockers, vasopressin, calcium channel blockers;
c) assess the necessity/possibility of artificial blood circulation
6. Thorough monitoring. After stabilization, continue close monitoring for 12 hours

25 % of cases, which is the highest rate among regional blocks [24], and this rate is significantly lower with subclavicular catheter placement. There is an assumption that the lower the mobility of anatomical structures in the location of the catheter, the more stable the position of the latter.

A catheter for prolonged anesthesia/analgesia may be incorrectly positioned initially, or may subsequently migrate [24, 25] or become occluded [23]. In case of displacement of the catheter, there is a risk of STLA development, and in some cases even myonecrosis [25]. The reasons for an ineffective block can be technical: disconnection of the syringe and the infusion extension, malfunction of the syringe dispenser. Individual anatomical features complicate the search for nerve structures, and genetic variations cause abnormal metabolism of the local anesthetic and lead to inadequate blockade. In addition, pain, as a multicomponent event, also includes psychological factors, such as anxiety and expectation of pain [26].

With the widespread introduction of US-navigation into clinical practice, the quality of CA increases significantly, the time of block administration is reduced [27, 28].

Discussion of the risk of ineffective anesthesia occurs during patient preparation for CA. In the process of this discussion, it is necessary to explain the possibilities of alternative blocks if the planned ones are ineffective, as well as options for traditional methods of anesthesia/analgesia, if repeated blocks are unacceptable.

Peripheral nerve damage is considered a rare complication of regional anesthesia. In the first days after block, the frequency of persistent symptoms of nerve dysfunction can reach 8–10 %, most patients recover within a few days or months [28, 29]. Complications that have not been compensated for in 6 months are considered irreversible from 0.015 to 0.09 % [30–32]. The frequency of complications during perineural catheterization is close to 0.21 % [33, 34]. The majority of nerve injuries are due to intraneural injection of anesthetic, and the greater the pressure, the more severe the injury [35, 36]. A comorbidity, for example, diabetes, can be an aggravating factor. If the patient experiences paresthesia or great resistance, the injection should be stopped. The use of US-navigation can significantly reduce the risk of nerve damage, as it allows visualization of the spread of the anesthetic. Symptoms of nerve damage are usually sensory, but depending on the affected nerve and the severity of the injury, it may also include motor components.

A large hematoma may form in case of accidental puncture of adjacent vessels under conditions of hypocoagulation. Usually, it can be prevented by direct pressure on the injection site, but in the case of a massive hematoma, surgical decompression may be necessary.

Allergy is a relatively rare complication. Anaphylaxis is not often observed. Allergic reactions may manifest as contact dermatitis or delayed (up to 72 hours) swelling at the injection site.

Infectious complications in the case of a single injection almost do not occur, and in cases of perineural catheterization, their probability does not exceed 3.2 % [36]. The risk of infection increases in conditions of injuries, critical conditions, weakened immunity, and the absence of antibacterial therapy. The risk can be reduced by removing the catheter within 48–72 hours after insertion.

Intoxication of the central nervous system by a local anesthetic (toxic left hemisphere syndrome) is manifested by ischemic symptoms in the absence of cerebral vascular occlusion. The hemispheric syndrome in the registered cases occurred on the contralateral side of the interscalene block. The probable cause may be cell death as a result of the neurotoxic effect of local anesthetics. Impairment of consciousness, slow-wave activity of electroencephalography in the affected hemisphere, epilepsy, global aphasia, dysphagia, dysarthria, facial nerve palsy, hemiparesis, signs of damage to the pyramidal tract, and complex behavioral changes were noted. In the immediate postoperative period, no abnormalities were observed on computer or magnetic resonance (MRI) tomograms. Hyperintensity of the gray matter of the cortex and basal ganglia was determined on the MRI after the operation from the 1st to the 5th day. To protect the respiratory tract, artificial ventilation of the lungs was necessary. Hospital stay ranged from 9 to 19 days. In most patients, a gradual improvement of the functional result was observed after a long course of rehabilitation, but residual symptoms persisted [37].

Conclusions

Regional anesthesia can be used in the pre-, intra- and postoperative periods, providing effective analgesia with a relatively small number of side effects compared to general anesthesia. In some cases, under the conditions of severe concomitant disorders, regional anesthesia may become the only possibility to anesthetize surgical intervention. Understanding the capabilities and limits of regional anesthesia by the surgical team is an important component of quality patient care.

Conflict of interest. The authors declare no conflict of interest.

References

1. Orthopedic Surgery — Global Trends & Opportunities. Report. Region: Global. — Life Science Intelligence, 2018. — 49 p.
2. Yentis S. M. Vassily von Anrep, forgotten pioneer of regional anesthesia / S. M. Yentis, K. V. Vlassakov // Anesthesiology. — 1999. — Vol. 90 (3). — P. 890–895. — DOI: 10.1097/00000542-199903000-00033.
3. Increased body mass index and ASA physical status IV are risk factors for block failure in ambulatory surgery - an analysis of 9,342 blocks / J. T. Cotter, K. C. Nielsen, U. Guller [et al.] // Canadian journal of anaesthesia. — 2004. — Vol. 51 (8). — P. 810–816. — DOI: 10.1007/BF03018454.
4. The risk of falls after total knee arthroplasty with the use of a femoral nerve block versus an adductor canal block: a double-blinded randomized controlled study / N. M. Elkassabany, S. Antosh, M. Ahmed [et al.] // Anesthesia and analgesia. — 2016. — Vol. 122 (5). — P. 1696–1703. — DOI: 10.1213/ANE.0000000000001237.
5. Ahdout J. Anesthesia patients with concomitant cardiac and hepatic dysfunction / J. Ahdout, M. Nurok // Anesthesiology clinics. — 2016. — Vol. 34(4), 731–745. https://doi.org/10.1016/j.anclin.2016.06.008.
6. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of Regional Anesthesia and Pain Medicine Evidence-Based Guidelines (Fourth Edition) / T. T. Horlocker, E. Vandermeuelen, S. L. Kopp [et al.] // Regional anesthesia and pain medicine. — 2018. — Vol. 43 (3). — P. 263–309. — DOI: 10.1097/AAP.0000000000000763.
7. Brachial plexus blocks for upper extremity orthopaedic surgery / B. G. Bruce, A. Green, T. A. Blaine, L. V. Wesner // The Journal of the American Academy of Orthopaedic Surgeons. — 2012. — Vol. 20 (1). — P. 38–47. — DOI: 10.5435/JAAOS-20-01-038.
8. Upper-extremity peripheral nerve blocks in the perioperative pain management of orthopaedic patients: AAOS exhibit selection / U. Srikumaran, B. E. Stein, E. W. Tan [et al.] // The Journal of bone and joint surgery. American volume. — 2013. — Vol. 95 (24). — P. e197(1–e197(13. — DOI: 10.2106/JBJS.L.01745.
9. https://ppt-online.org/166291
10. Urmey W. F. One hundred percent incidence of hemidiaphragmatic associated with interscalene brachial plexus anesthesia as diagnosed by ultrasonography / W. F. Urmey, K. H. Talts, N. E. Sharrock // Anesthesia and analgesia. — 1991. — Vol. 72 (4). — P. 498–503. — DOI: 10.1213/00000539-199104000-00014.
11. Effect of interscalene brachial plexus block on the pulmonary function of obese patients: a prospective, observational cohort study / M. S. Melton, H. E. Monroe, W. Qi [et al.] // Anesth Analg 2017; Anesthesia and analgesia. — 2017. — Vol. 125 (1). — P. 313–319. — DOI: 10.1213/ANE.0000000000002180.
12. Russon K. Upper limb blocks / K. Russon, T. Pickworth, W. Harrop-Griffiths // Anaesthesia. — 2010. — Vol. 65 (Suppl 1). — P. 48–56. — DOI: 10.1111/j.1365-2044.2010.06277.x.
13. Incidence of diaphragmatic paralysis following supraclavicular brachial plexus block and its effect on pulmonary function / P. H. K. Mak, M. G. Irwin, C. G. C. Ooi, B. F. M. Chow // Anaesthesia. — 2001. — Vol. 56. — P. 352—356. — DOI: 10.1046/j.1365-2044.2001.01708-2.x.
14. Ultrasound-guided supraclavicular block: outcome of 510 consecutive cases / A. Perlas, G. Lobo, N. Lo [et al.] // Regional anesthesia and pain medicine. — 2009. — Vol. 34 (2). — P. 171–176. — DOI: 10.1097/AAP.0b013e31819a3f81.
15. Desroches J. The infraclavicular brachial plexus block by the coracoid approach is clinically effective: an observational study of 150 patients / J. Desroches // Canadian journal of anaesthesia. — 2003. — Vol. 50 (3). — P. 253–257. — DOI: 10.1007/BF03017794.
16. Neal J. M. American Society of Regional Anesthesia and Pain Medicine Local Anesthetic Systemic Toxicity checklist: 2020 version / J. M. Neal, E. J. Neal, G. L. Weinberg // Regional anesthesia and pain medicine. — 2021. — Vol. 46 (1). — P. 81–82. — DOI: 10.1136/rapm-2020-101986.

17. Local anesthetic systemic toxicity: a narrative literature review and clinical update on prevention, diagnosis, and management / M. Gitman, M. R. Fettiplace, G. L. Weinberg [et al.] // Plastic and reconstructive surgery. — 2019. — Vol. 144 (3). — P. 783–795. — DOI:10.1097/PRS.0000000000005989.
18. Dickerson D. M. Local anesthetic systemic toxicity / D. M. Dickerson, J. L. Apfelbaum // Aesthetic surgery journal. — 2014. — Vol. 34 (7). — P. 1111–1119. — DOI: 10.1177/1090820X14543102.
19. Harvey M. Lipid emulsion in local anesthetic toxicity / M. Harvey, G. Cave // Current opinion in anaesthesiology. — 2017. — Vol. 30 (5). P. 632–638. — DOI: 10.1097/ACO.0000000000000498.
20. Lower extremity regional anesthesia: essentials of our current understanding / D. Q. Tran, F. V. Salinas, H. T. Benzon, J. M. Neal // Regional anesthesia and pain medicine, rapm-2018-000019. — 2019. — Advance online publication. — DOI: 10.1136/rapm-2018-000019.
21. ASRA checklist improves trainee performance during a simulated episode of local anesthetic systemic toxicity / J. M. Neal, R. L. Hsiung, M. F. Mulroy [et al.] // Regional anesthesia and pain medicine. — 2012. — Vol. 7 (1). — P. 8–15. — DOI: 10.1097/AAP.0b013e31823d825a.
22. Yeniocak T. Retrospective analysis of ultrasound-guided infraclavicular block: effect of experience of anesthesiologists on volume of local anesthetic administered / T. Yeniocak, N. Canbolat // Pain research & management. — 2019. — Vol. 2019. — Article ID: 4846956. — DOI: 10.1155/2019/4846956.
23. Ahsan ZS, Carvalho B, Yao J. Incidence of failure of continuous peripheral nerve catheters for postoperative analgesia in upper extremity surgery / Z. S. Ahsan, B. Carvalho, J. Yao // The Journal of hand surgery. — 2014. — Vol. 39 (2). — P. 324–329. — DOI: 10.1016/j.jhsa.2013.11.011.
24. Salinas F. V. Location, location, location: Continuous peripheral nerve blocks and stimulating catheters / F. V. Salinas // Regional anesthesia and pain medicine. — 2003. — Vol. 28 (2). — P. 79–82. — DOI: 10.1053/rapm.2003.50033.
25. Jenkins C. R. An unusual complication of interscalene brachial plexus catheterization: delayed catheter migration / C. R. Jenkins, M. K. Karmakar // British journal of anaesthesia. — 2005. — Vol. 95 (4). — P. 535–537. — DOI: 10.1093/bja/aei217.
26. Effect of patient-controlled perineural analgesia on rehabilitation and pain after ambulatory orthopedic surgery: a multicenter randomized trial / X. Capdevila, C. Dadure, S. Bringuier [et al.] // Anesthesiology. — 2006. — Vol. 105 (3). — P. 566–573. — DOI: 10.1097/00000542-200609000-00022.
27. Koscielniak-Nielsen ZJ. Ultrasound-guided peripheral nerve blocks: what are the benefits? Acta anaesthesiologica Scandinavica. — 2008. — Vol. 52 (6). — P. 727–737. — DOI: 10.1111/j.1399-6576.2008.01666.x.
28. A prospective, randomized, controlled trial comparing ultrasound versus nerve stimulator guidance for interscalene block for ambulatory shoulder surgery for postoperative neurological symptoms / S.S. Liu, V. M. Zayas, M. A. Gordon [et al.] // Anesthesia and analgesia. — 2009. — Vol. 109 (1). — P. 265–271. — DOI:10.1213/ane.0b013e3181a3272c.
29. Fredrickson M. J. Neurological complication analysis of 1000 ultrasound guided peripheral nerve blocks for elective orthopaedic surgery: a prospective study / M. J. Fredrickson, D. H. Kilfoyle // Anaesthesia. — 2009. — Vol. 64 (8). — P. 836–844. — DOI: 10.1111/j.1.
30. Incidence of local anesthetic systemic toxicity and postoperative neurologic symptoms associated with 12,668 ultrasound-guided nerve blocks: an analysis from a prospective clinical registry / B. D. Sites, A. H. Taenzer, M. D. Herrick [et al.] // Regional anesthesia and pain medicine. — 2012. — Vol. 37 (5). — P. 478–482. — DOI: 10.1097/AAP.0b013e31825cb3d6.
31. Major complications of regional anesthesia in France: The SOS Regional Anesthesia Hotline Service / Y. Auroy, D. Benhamou, L. Bargues [et al.] Anesthesiology. — 2002. — Vol. 97 (5). — P. 1274–1280. — DOI: 10.1097/00000542-200211000-00034.
32. Comprehensive Analysis of 13,897 Consecutive Regional Anesthetics at an Ambulatory Surgery Center / R. J. Malchow, R. K. Gupta, Y. Shi [et al.] // Pain medicine (Malden, Mass.). — 2018. — Vol. 19 (2). — P. 368–384. — DOI:10.1093/pm/pnx045.
33. Continuous peripheral nerve blocks in hospital wards after orthopedic surgery: a multicenter prospective analysis of the quality of postoperative analgesia and complications in 1,416 patients / X. Capdevila, P. Pirat, S. Bringuier [et al.] // Anesthesiology. — 2005. — Vol. 103 (5). — P. 1035–1045. — DOI: 10.1097/00000542-200511000-00018.
34. The feasibility and complications of the continuous popliteal nerve block: a 1001-case survey / A. Borgeat, S. Blumenthal, M. Lambert [et al.] // Anesthesia and analgesia. — 2006. — Vol. 103 (1). — DOI: 10.1213/01.ane.0000221462.87951.8d.
35. Neurologic and histologic outcome after intraneural injections of lidocaine in canine sciatic nerves / E. Kapur, I. Vuckovic, F. Dilberovic [et al.] // Acta anaesthesiologica Scandinavica. — 2007. — Vol. 51 (1). — P. 101–107. — DOI: 10.1111/j.1399-6576.2006.01169.x.
36. Capdevila X. Infectious risk of continuous peripheral nerve blocks / X. Capdevila, S. Bringuier, A. Borgeat // Anesthesiology. — 2009. — Vol. 110 (1). — P. 182–188. — DOI: 10.1097/ALN.0b013e318190bd5b.
37. Local anesthetic-induced central nervous system toxicity during interscalene brachial plexus block: a case series study of three patients / D. Spitzer, K. J. Wenger, V. Neef [et al.] // Journal of clinical medicine. — 2021. — Vol. 10 (5). — Article ID : 1013. — DOI: 10.3390/jcm10051013.

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MODERN POSSIBILITIES OF UPPER EXTREMITY REGIONAL ANESTHESIA

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