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# THE CHOICE OF THE MOST OPTIMAL METHOD OF ANESTHESIA FOR OPERATION ON THE LOWER EXTREMITY VESSELS

**Yernar D. Mamyrov[1], https://orcid.org/0000-0003-4070-2165**

**Daulet U. Mamyrov[1], https://orcid.org/0000-0001-7887-1736**

**Gulzhanat E. Jakova[2], https://orcid.org/0000-0002-9479-5419**

**Yoshihiro Noso[3], https://orcid.org/0000-0003-3477-1260**

**Marat K. Syzdykbaev[4], https://orcid.org/0000-0002-0561-4111**

**[1] Pavlodar Branch of NCJSC "Semey Medical University", Department of Emergency Medicine, Obstetrics and Gynecology, Pavlodar, Kazakhstan;**
**[2]Department of Surgery, Pavlodar Branch of NCJSC Semey Medical University, Pavlodar, Kazakhstan**
**[3] Hiroshima International University, Department of Health Services Management, Hiroshima, Japan;**
**[4] NCJSC "Semey Medical University", Department of Surgery, Anesthesiology and Reanimatology, Semey, Republic of Kazakhstan.**

**Summary**

**Introduction.** Varicose veins (VV) are characterized by saphenous, dilated, tortuous veins measuring three millimeters or more, involving the saphenous veins, saphenous tributaries, or superficial veins of the legs. Manifestations of varicose veins range from limited discomfort in the legs to swelling and non-healing ulcers, sometimes leading to disability. The frequency and severity of these symptoms are directly related to age and gender. Due to the high variability of localization and the degree of involvement of the venous network, there are various methods of surgical treatment of this pathology, as well as a variety of methods of anesthesia with their inherent positive and negative qualities.

**Aim.** To analyse literature reflecting modern ideas about the prevalence of varicose veins of the lower extremities, methods of surgical treatment and a reasonable choice of the safest and most effective method of anesthesia.

**Search strategy.** The search for publications was carried out in the following databases: PubMed, Embase, Scopus, Web of Science, e-Library and Cyberleninka. Key queries included the following terms: chronic venous insufficiency, varicose veins, phlebectomy, crossectomy, regional anesthesia, spinal anesthesia, epidural anesthesia, unilateral spinal anesthesia. The search depth was 20 years, works from earlier years that were of high scientific value on this topic were also included.

**Results and conclusions.** The degree of quality of pain relief during VV surgeries, its duration, and comfort for the patient and operating team are highly variable. The key factors are the number of complications associated with dural puncture, patient satisfaction and time to recovery from anesthesia. The use of a choice of modern methods of anesthesia, such as unilateral spinal anesthesia (USA), allows us to avoid most of the adverse effects of spinal anesthesia, while USA supplemented with electrical nerve stimulation increases the safety of anesthesia, has high selectivity, and allows to anesthetize only one lower limb of the patient.

***Keywords:*** *varicose veins, spinal anesthesia, epidural anesthesia, unilateral spinal anesthesia.*

**Резюме**

# ВЫБОР НАИБОЛЕЕ ОПТИМАЛЬНОГО МЕТОДА АНЕСТЕЗИИ ПРИ ОПЕРАЦИЯХ НА СОСУДАХ НИЖНИХ КОНЕЧНОСТЕЙ

**Ернар Д. Мамыров[1], https://orcid.org/0000-0003-4070-2165**

**Даулет У. Мамыров[1], https://orcid.org/0000-0001-7887-1736**

**Гульжанат Е. Джакова[2], https://orcid.org/0000-0002-9479-5419**

**Йошихиро Носо[3], https://orcid.org/0000-0003-3477-1260**

**Марат К. Сыздыкбаев[4], https://orcid.org/0000-0002-0561-4111**

**[1] Кафедра неотложной медицины, акушерства и гинекологии, Павлодарский филиал НАО «Медицинский университет Семей»,**
**г. Павлодар, Казахстан;**
**[2]Кафедра хирургии, Павлодарский филиал НАО «Медицинский университет Семей»,**
**г. Павлодар, Казахстан;**
**[3] Кафедра Управления службами здравоохранения, Международный Университет г. Хиросима, Япония;**
**[4] Кафедра госпитальной хирургии, анестезиологии и реаниматологии, НАО «Медицинский университет Семей», г. Семей, Казахстан.**

**Введение.** Варикозное расширение вен (ВРВ) характеризуется подкожными, расширенными, извитыми венами размером от трех и более миллиметров, вовлекающим подкожные вены, подкожные притоки или поверхностные вены ног. Проявления ВРВ самые разнообразные: от ограниченного дискомфорта в ногах до отека и незаживающих язв, иногда приводящих к потере трудоспособности. Частота проявлений и тяжесть этих симптомов напрямую зависят от возраста и половой принадлежности. Ввиду высокой вариабельности локализации, и степени вовлечения венозной сети, имеются различные методы хирургического лечения данной патологии, равно как и разнообразие методов обезболивания с присущими им положительными и отрицательными качествами.

**Цель.** Провести анализ литературы, отражающей современные представления о распространенности ВРВ нижних конечностей, методах хирургического лечения и обоснованного выбора наиболее безопасного и эффективного метода анестезиологического пособия.

**Стратегия поиска.** Поиск публикаций проводился в базах данных: PubMed, Embase, Scopus, Web of Science, e-Library и Cyberleninka. Ключевые запросы включали следующие термины: хроническая венозная недостаточность, варикозное расширение вен, флебэктомия, кроссэктомия, региональная анестезия, спинальная анестезия, эпидуральная анестезия, односторонняя спинальная анестезия. Глубина поиска была 20 лет, однако были включены работы более ранних лет, имеющих высокую научную ценность по данной теме.

**Результаты и выводы.** Степень качества обезболивания при операциях на ВРВ, ее длительность, комфорт для пациента и операционной бригады весьма вариабельны. Ключевым фактором является количество осложнений связанных с пункцией твердой мозговой оболочки, степень удовлетворенности пациента и время до активизации после анестезии. Использование в качестве анестезии выбора современных методов, таких как односторонняя спинальная анестезия (ОСА), позволяют избежать большинства нежелательных явлений спинальной анестезии, в то время как ОСА дополненная электронейростимуляцией, повышает безопасность анестезии, а также обладают высокой селективностью, позволяя обезболить только одну нижнюю конечность пациента.

***Ключевые слова:*** *варикозное расширение вен, спинальная анестезия, эпидуральная анестезия, односторонняя спинальная анестезия.*

**Түйіндеме**

# АЯҚ ТАМЫРЛАРЫНА ОПЕРАЦИЯ ЖАСАУ КЕЗІНДЕ АНЕСТЕЗИЯНЫҢ ЕҢ ОҢТАЙЛЫ ӘДІСІН ТАҢДАУ.

**Ернар Д. Мамыров[1], https://orcid.org/0000-0003-4070-2165**

**Даулет У. Мамыров[1], https://orcid.org/0000-0001-7887-1736**

**Гульжанат Е. Джакова[2], https://orcid.org/0000-0002-9479-5419**

**Йошихиро Носо[3], https://orcid.org/0000-0003-3477-1260**

**Марат К. Сыздыкбаев[4], https://orcid.org/0000-0002-0561-4111**

**[1]Шұғыл медицина, акушерлік және гинекология кафедрасы, "Семей Медицина университеті" КЕАҚ Павлодар филиалы, Павлодар қ., Қазақстан;**
**[2]Хирургия кафедрасы, "Семей Медицина университеті" КЕАҚ Павлодар филиалы, Павлодар қ., Қазақстан;**
**[3]Денсаулық сақтау қызметтерін басқару кафедрасы, Хиросима Халықаралық университеті, Хиросима қ., Жапония;**
**[4] "Семей Медицина университеті" КЕАҚ, Госпитальдық хирургия, анестезиология және реаниматология кафедрасы, Семей қ., Қазақстан.**

**Кіріспе.** Көктамырлардың варикоздық кеңеюі (КВК) тері астындағы тамырлардың, тері астындағы салалардың немесе аяқтың беткі тамырларын қамтитын үш немесе одан да көп миллиметрлік тұрақты түрде кеңейген көктамырлардың өзгерістерімен сипатталады. Негізгі КВК көріністеріне аяқтың шектеулі ыңғайсыздықтан, ісіну мен жазылмайтын терінің ойық жараларға дейін, кейде мүгедектікке әкелетін көріністер жатады. Бұл белгілердің көріну жиілігі мен ауырлығы, науқастың жасына және жынысына тікелей байланысты. Локализацияның жоғары өзгергіштігіне және көктамырлар желінің қатысу дәрежесіне байланысты бұл патологияны хирургиялық емдеу әдістері әртүрлі болып келеді. Соған сәйкес оларға тән оң және теріс қасиеттері бар анальгезия әдістерінің де ерекшеліктері бөлек болып табылады.

**Зерттеу мақсаты.** Аяқ көктамырланының варикозды кеңеюінің таралуы, хирургиялық емдеу әдістері және анестезиологиялық құралдардың ең қауіпсіз және тиімді әдістерін таңдау туралы заманауи ой көрсететін және заманауи әдебиеттерге негізделген талдау жасау.

**Іздеу стратегиясы.** Жарияланымдарды іздеу: PubMed, Embase, Scopus, Web of Science, e-library және cyberleninka дерекқорларда жүргізілді. Негізгі сұраулардың қатарына келесі терминдер кірді: созылмалы веноздық жеткіліксіздік, варикозды тамырлар, флебэктомия, кроссэктомия, аймақтық анестезия, жұлын анестезия, эпидуральды анестезия, бір жақты жұлын анестезиясы. Іздеу тереңдігі 20 жыл болды, дегенмен, бұл тақырып бойынша жоғары ғылыми құндылығы бар бұрынғы жылдардағы еңбектері де кірді.

**Зерттеу нәтижелері мен қорытындылары.** КВК операциялары кезінде ауырсынуды жеңілдету сапасының дәрежесі, оның ұзақтығы және пациент пен операциялық топ үшін жайлылық өте өзгермелі. Дуральды пункцияға

байланысты асқынулардың саны, пациенттің қанағаттануы және анестезиядан кейін қалпына келтіру уақыты жұлын жансыздандырудың негізгі факторлар болып табылады. Біржақты жұлын анестезиясы (БЖА) сияқты заманауи әдістерді таңдау, жұлын анестезиясының көптеген жағымсыз әсерлерін болдырмауға мүмкіндік береді, ал электрлік нейростимуляциямен толықтырылған БЖА, науқас қауіпсіздігін арттырады, және тек бір төменгі аяқтарын жансыздандыруға мүмкіндік береді.

***Түйінді сөздер:*** *варикозды тамырлар, жұлын анестезиясы, эпидуральды анестезия, бір жақты жұлын анестезиясы.*

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**Introduction**

Varicose veins (VV) are characterized by tortuous, dilated, saphenous veins that measure three millimeters or more, involving the saphenous veins, saphenous tributaries, or superficial veins of the legs. At the same time, age and family history are considered important risk factors [10].

VV is the most common clinical manifestation of chronic venous disease [47]. VV include many clinical and pathological manifestations, from limited discomfort in the legs to swelling and nonhealing ulcers, sometimes leading to disability [74, 97], as the frequency and severity of these symptoms are directly related to age and gender [93].

Due to the high variability of localization and the degree of involvement of the venous network, there are various surgical treatment ways of this problem, as well as a variety of anesthesia methods with their inherent positive and negative qualities.

**Aim:** to analyze the literature that reflects modern ideas about the prevalence of VV in the lower extremities, surgical treatment methods and a reasonable choice of the safest and most effective method of anesthesia.

**Search strategy:** The study includes publications taken for analysis from the most relevant databases such as PubMed, Embase, Scopus, Web of Science, e-Library and Cyberleninka.

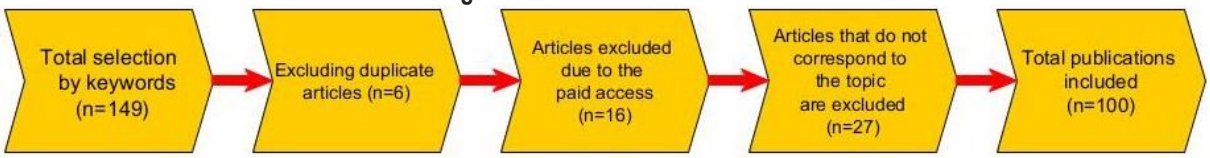
*The inclusion criteria* for the articles included literature reviews and meta-analyses, but in the absence of such, data from randomized clinical trials, books and patents were also included.

*The exclusion criteria were:* articles in foreign languages other than Russian and English, abstracts (resumes), newspaper articles, articles with unconfirmed scientific information, as well as studies with signs of violation of the methodology of clinical, observational and any other studies.

Key queries included the following terms: chronic venous insufficiency, varicose veins, phlebectomy, crossectomy, regional anesthesia, spinal anesthesia, epidural anesthesia, unilateral spinal anesthesia. The search depth was 20 years, works from earlier years (1933, 1951, 1990, 1995 years) that were of high scientific value on this topic were also included.

Initially, according to search queries and keywords, 149 articles were found, and then 6 duplicate articles were excluded, mostly in Russian, published in the e-library and cyberleninka databases. We also excluded 16 works published in databases that required paid access. In addition, 27 papers that did not correspond to the topic of the review were excluded. In total, out of 149 articles, 100 scientific papers were selected for review.

**Figure 1. Article selection chart**




**Search results and discussion:**

**Varicose veins, chronic vein diseases: a brief description.**

Etiologically, the most common risk factors for VV are hereditary predisposition, gender, number of pregnancies and births, use of combined oral contraceptives, overweight, sedentary lifestyle, constipation, history of venous thrombosis, occupational activities that involve prolonged standing or sitting, and bad habits, the main of which is smoking [52, 92, 97].

To more accurately determine the prevalence of chronic venous diseases (CVD), in 1994, a clinical, etiological, anatomical, and pathoanatomical classification (CEAP) was introduced, whose revision was in 2004, the latest version was adopted in 2020 [34, 63]. This classification is based on clinical manifestations (C), etiological factors (E), the anatomical distribution of the disease (A) and basic pathophysiological findings (P). VV are included in category C2 in this classification. Despite the multifactorial

pathogenesis of VV, the contributing genetic and environmental factors are not well studied [42].

The epidemiology of VV is represented by an incidence of 30% in the general population, with rates significantly higher in the elderly [87]. In general, VV are more common in women than in men. Therefore, the Framingham study tested the presence of VV every two years for 16 years. Consequently 23 and 30 percent of the male and female population developed VV during observation. The two-year incidence ranged from 39.4 to 51.9 per 1000. The incidence was highest in women aged 40 years [12]. There is an obvious correlation of race with the prevalence of VV. Consequently, the prevalence of chronic venous insufficiency (CVI) and VV in Asians is lower than in white non-Hispanics [98]. The Edinburgh vein study can be distinguished with an incidence of VV of 11.5% in 18 to 24 years of age, while as a category of 55 to 64 years, it showed an incidence of 55.7% [38]. The equally well-known Bonn Vein study, conducted in Germany, showed the prevalence of the C2 class of CVD we are considering at 14.3% [77]. The results of one of the latest extensive CVD studies, called the Vein Consult program, conducted in 23 countries and included 99359 patients, were published relatively recently, in 2018. The countries were divided into four main regions, Asia, Eastern Europe, Western Europe, and Latin America, where the total prevalence of CVD classes C1-C6 in these regions was 69.94%, CVI combines classes C3-C6 and amounted to 32.3%. If we evaluated the frequency of CVD by region, then the countries of eastern Europe showed the highest prevalence (70.18%), and the lowest frequency were the Asian countries (51.93%) [94].

**Surgical methods for the treatment of varicose veins and CVD-C2 class and higher**

The main goal of the surgery is to ligate and disconnect the great saphenous vein (GSV) and/or small saphenous vein (SSV) at its junction with the deep vein system. The choice of method is based on the location, size and extent of the venous lesion, the presence or absence of venous reflux. Unilateral surgery for bilateral varicose lesions of the lower extremities is preferable, both for the surgical team and for the patient. After all, most of the complications of a single-stage bilateral operation were mainly associated with the duration of the operation, the need to increase anesthetic doses, and sometimes additional intraoperative administration of analgesics, as well as the corresponding blood loss [32]. A unilateral operation is more beneficial mainly to avoid the above reasons, as well as due to the double hospitalization and the almost double income of hospitals [76].

Surgeries are represented by high ligation of vessels with venous extraction, as well as ligation of associated anastomoses in the case of insufficiency of the perforating veins. These methods have been developed and studied for more than 50 years. Minimally invasive methods of treating VV, such GSV and SSV ablation using laser, radiofrequency or foam sclerotherapy, are also gaining popularity, but traditional surgery remains the gold standard for the treatment of VV [96]. Taking into account the high adherence of the population to minimally invasive treatment methods for VV, surgical treatment is the most reliable method, despite the recurrence rate in a 5-year period of 25 to 50% [22, 84].

In the surgical treatment of VV and insufficiency of the GSV, SSV, the following surgical interventions can be called the main [78]:

- Operation to remove the GSV, most often invagination, with or without ligation of the saphenofemoral junction (SFJ) [29]. Simple SFJ ligation, except in obese patients, can be performed under local anesthesia, but removal of the GSV usually requires regional or general anesthesia [59]. There is also evidence of a lower incidence (7%) of damage to the saphenous femoral nerve in the case of removal of the GSV by the knee level, when damage to the saphenous femoral nerve reached 39% with complete removal of the GSV [50].

- The ligation of the saphenofemoral anastomosis is an effective surgery in terms of a lower incidence of recurrence of VV and has variations in implementation. In a study by Winterborn et al., in which flush SFJ ligation was performed in 95 cases versus 114 cases of standard saphenofemoral stump ligation. All patients were followed up for two years, and ultimately recurrence rates were 32% and 33%, respectively [95].

There is also a variant of SFJ resection and ligation with endothelial inversion with screw sutures, which showed recurrence and neovascularization of VV with a frequency from 43 to 49% [49].

- Operation of isolating the saphenopopliteal fistula, without removing the SSV. The main difference is the position of the patient on the operating table on the side or prone. Furthermore, the anatomy of the popliteal region is characterized by great variability, in connection with which a preoperative ultrasound examination and marking of the position of the saphenopopliteal anastomosis was recommended [35]. During the operation, after the isolation of the SSV, there are two options for the operation - the allocation of the subcutaneous popliteal fistula and its flush ligation; the second option is the proximal ligation of the SSV as deep as possible in the popliteal fossa. The recurrence rate of VV with this type of surgery reaches 20% after one year [73].

- SSV removal operation, where it is removed to the middle of the lower leg, or the removal of the upper part of the vein is sufficient. In a study by O'Hare et al., evaluating the results of SSV surgery at one year, there was a reduction in the recurrence rate of VV in patients who had SSV removed, without any increase in numbness. Incompetence of subcutaneous popliteal anastomosis, detected by duplex examination, was significantly lower in those who underwent removal of SSV [73].

- Surgical treatment of insufficiency of perforated veins of the lower extremities:

In case of valve insufficiency of perforating veins in CVI, in the first half of the twentieth century, the operations of Cockett, Linton, and Felder were proposed. In the first two cases, the incision is made along the medial surface of the lower leg (Linton line). With the Cockett method, the perforating veins are ligated epifascially and with the Linton method subfascially. But often along the line of Linton, there were trophic changes in the skin and subcutaneous fat (fibrosis). Incisions in these areas are fraught with postoperative complications and poor healing. And the isolation of the epifascial veins due to subcutaneous fat

fibrosis made Cockett's operation difficult. Therefore, Linton's method [31, 62] gained quite a lot of popularity.

**Anesthesiological support of operations on varicose veins of the lower extremities**

All of the above options for the surgical treatment of CVD of the lower extremities require reliable anesthesia, as surgical intervention causes tissue damage, which activates the systemic inflammatory response and leads to changes in the endocrine and metabolic systems [86]. The resulting imbalance can lead to partial, and, in some cases, complete organ dysfunction, and an increase in the frequency of postoperative complications. There are other factors, such as anesthesia, pain, blood transfusion, and elevated blood glucose, that have an important impact on the current state of homeostasis. The joint work of the surgeon and the anesthesiologist can prevent the above disorders, using less aggressive surgical and anesthetic methods [70]. Modulation of pain perception by appropriate analgesia leads to a decrease in the level of pro-inflammatory cytokines and an increase in lymphocyte activity [18]. Next, the most relevant types of anesthesia in CVI surgery will be considered.

***Tumescent anesthesia***

Minimally invasive methods of VV treating, which include endovenous laser ablation (EVLA), radiofrequency ablation (RFA) and stem sclerotherapy (SS), can be performed under tumescent anesthesia (TA), which is a type of infiltration anesthesia, and is an injection into the subcutaneous fat layer of a large volume of low concentration anesthetic. This type of anesthesia was first described by Klein in 1986 [53]. As a pharmacologist and dermatologist, Klein has established through a systematic series of plasma lidocaine dilution and testing that large volumes of diluted anesthetic injected directly into subcutaneous adipose tissue can safely provide superior local anesthesia. For successful application of TA, it is necessary to know the minimum effective concentration and the maximum safe dose of lidocaine.

Minimum effective dose of lidocaine during TA

1% lidocaine with epinephrine is commonly used for local anesthesia. A dose of 7 mg/kg has traditionally been considered the maximum dose of lidocaine, so a patient weighing 60 kg can safely inject about 40 ml of 1% lidocaine with epinephrine. However, to perform operations in large areas, Klein had to dilute the local anesthetic solution due to insufficient volume. Although 0.4% lidocaine was considered the minimum effective lidocaine concentration, Klein found that dilution of the local anesthetic at 0.05% to 0.1% lidocaine was able to provide superior anesthesia in the subcutaneous space [55].

Maximum safe dose of lidocaine during TA

When using large doses of lidocaine, it is important to have a clear idea not only of the quality of pain relief when using it, but also of its toxicity. Moreover, timely recognition of early signs of local anesthetic toxicity is of particular importance [54]. Subjective side effects such as dizziness, nausea, euphoria, restlessness, and drowsiness occur at plasma levels of lidocaine between 3 and 6 mg/mL. Objective signs of toxicity such as vomiting, tremors, tinnitus, blurred vision, psychosis, and muscle fasciculations occur at plasma lidocaine levels greater than 5 mg/ml. Plasma levels of lidocaine above 8 mg/ml can cause convulsions and cardiopulmonary failure. Coma followed by respiratory and cardiac arrest occurs when the level of lidocaine in the blood plasma is above 12 mg/ml [75].

Thus, the TA solution is diluted concentrations of lidocaine (0.05-0.1% or 500-1000 mg/l), epinephrine (0.65-1 mg/l) and bicarbonate (10 mEq/l) in physiological solution. The exact composition of the tumescent anesthetic mixture should be appropriate for its intended clinical use. In the case of the use of TA in phlebology, the concentration of the solution should be from 0.05 to 0.075% lidocaine. Sensitive areas such as the chest, chin, and cheeks require higher concentrations of lidocaine to achieve adequate anesthesia. The maximum dose of lidocaine administered should be less than 55 mg/kg. Further development toward patient safety led to the development of Sutler's solution for TA, based on prilocaine, which reduced the risks of systemic toxicity in the use of lidocaine. However, when using prilocaine, the formation of methemoglobin is possible, which limits its use [14]. One of the last anesthetics for TA was articaine, due to its high analgesic effect and low toxicity and fast half-life. Articaine is more potent than lidocaine and prilocaine and less toxic than bupivacaine, ropivacaine, and mepivacaine [39, 71].

***Epidural anesthesia***

Epidural anesthesia (EA) is a method of perioperative pain relief that has many applications in anesthesiology. It is useful as a primary anesthesia, but is also used as an adjunct to pain relief. It can be a single injection or a continuous infusion for long-term pain relief. In addition to providing high-quality analgesia, ensuring stable hemodynamics, the use of EA potentiates the effect of other anesthetics and analgesics, its doses are reduced, and therefore the incidence of side effects [69]. In addition, there is evidence that EA reduces cortisol levels, accelerates motility recovery, reduces the incidence of pulmonary embolism and deep vein thrombosis in the postoperative period, and reduces hospital stay [68, 91].

The epidural space of the spine contains adipose and connective tissues, as well as blood vessels and lymphatic ducts. These vessels may dilate during pregnancy or ascites, increasing the likelihood of vascular puncture. The distance from the skin surface to the epidural space varies with age or weight. It can range from 4 cm in adults of normal weight to 8 cm or more in obese patients. The main approaches to the epidural space are the median and paramedian approaches, with the patient sitting or lying on his side. The main stages of EA are: the introduction of 1% lidocaine into the skin and underlying tissues, the passage of an epidural needle through the skin, subcutaneous tissue, supraspinous and interspinous ligaments. Once there, the stylet must be removed and a syringe filled with saline must be attached to the needle to properly perform the loss-of-resistance test. Under the positive pressure exerted on the syringe plunger, the needle is moved further, and after the ligamentum flavum puncture, a sharp decrease in pressure in the syringe is observed, which indicates that it has entered the epidural space - this is a resistance loss test [44].

The most common complication of EA, as with other neuraxial techniques, is hypotension due to sympathetic blockade. A decrease in vascular resistance leads to increased blood flow to blocked segments. In some cases,

bradycardia and a decrease in cardiac output are observed, depending on the spread of a local anesthetic in the epidural space [60]. Positive volemic status is the main prerequisite to ensure venous return to the heart and thus maintaining cardiac output and blood pressure [79].

***Spinal anesthesia***

Since the first detailed description of the spinal anesthesia (SA) technique, namely since 1898, when Carl *August Bier* and his assistant performed SA on each other [21], this type of anesthesia has spread rapidly throughout the world. The spinal tap technique is learned early in anesthesiologist training, and technical competence is quickly acquired, after 40–70 controlled attempts [56]. All these factors led to a significant increase in the number of spinal anesthesias in the overall structure of anesthesia methods, due to the relative speed of this type of anesthesia and the reduction in the number of bed days [81, 82]. Factors that deserve attention are also the comparable duration of surgery between SA and general anesthesia, the high quality of pain relief and muscle relaxation [61].

Anatomically, the spinal cord is a well-organized cylindrical formation that originates at the foramen magnum at the base of the skull, as a continuation of the medulla oblongata. It is located in the spinal canal. In men, the length of the spinal cord is up to 45 cm, in women up to 43 cm [11].

The subarachnoid space also originates from the foramen magnum and extends to the second sacral segment (S2), delimited by the arachnoid and pia mater and below by the sacrococcygeal membrane. The spinal cord contains the spinal cord roots, cerebrospinal fluid (CSF), large blood vessels, and cisterns. The cisterns are enlarged pockets of CSF, formed by separation of the arachnoid from the pia mater, depending on the anatomy of the surface of the brain and spinal cord.

In the thoracic region, the width of the spinal cord ranges from 6.4 to 8.3 mm, and in the cervical and lumbar regions, from 12.7 to 13.3 mm. The C5 segment has the largest transverse diameter of 13.3 ± 2.2 mm, decreases to 8.3 ± 2.1 mm at the T8 level and increases to 9.4 ± 1.5 mm at the L3 level. The diameter of the spinal canal at the level of the cervical segments is up to 25 mm, narrowing to 17 mm in the thoracic segment and widening from 22 mm to 27 mm in the lumbar segment, with an anterior-posterior dimension of 15-16 mm throughout the canal [20, 41].

Technically, SA and EA for VV is performed medially in the lumbar region, at the level of the middle and lower lumbar [85]. To avoid damage to the spinal cord and to minimize the effect of intrathecal anesthetics on the upper thoracic and cervical regions, the SA needle is usually inserted into the L3-L4 or L4-L5 gap. Spinal cord injury is most likely when choosing higher spaces between the spines, especially in obese patients [23].

When the needle is inserted, the latter, as with EA, reaches the epidural space, and without removing the stylet, the dura mater is punctured. It is known that anesthesiologists also focus on the "failure" and "click" sensation during dura puncture, which is a subjective criterion, which, according to some authors, may be different in strength depending on the type of needle tip, its diameter, and anatomical features of the patient. Thus, the above-mentioned subjective criteria become vaguer when using atraumatic pencil-point needles [48]. At the same time, sensations during puncture of the dura mater with needles that are passed through the introducer due to the high flexibility of thin needles, starting from 25 Gauge, may be almost completely absent. The main objective criterion, in classical SA, is the outflow of CSF from the lumen of the spinal needle [21, 66]. At the same time, when using 27G thin needles, the lumen of the needle is so small that, to obtain CSF in the needle cannula, it is sometimes necessary to wait for it to appear in the needle pavilion for up to 20 seconds [83].

Many works have been devoted to the complications that are common to SA and EA. One of the main ones is intraoperative hypotension after the onset of sympathetic blockade, which varies from 13% to 33% in general surgical patients [43, 46], and up to 70-90% in obstetric patients [40]. Even taking into account the preoperative infusion load, the incidence of hypotension could reach 40% or more [99].

In addition to hypotension, it is necessary to take into account the high risk of post-puncture headache (PDPH), the frequency of which is 0.16-1.3% of cases [45], according to other authors, from 1 to 40% [17], depending on the type, the diameter of the needle and its direction, the presence of concomitant risk factors and the competence of the anesthesiologist. A concomitant and unpleasant complication can be called postoperative acute urinary retention in SA with a frequency of 5% to 70% [15]. It is also necessary to be aware of the development of more pronounced cognitive impairment in the patient with bilateral spinal blockade, which increases the frequency of such disorders as the disorders of bladder function mentioned above and weakness in the lower extremities after anesthesia. Subtotal and total spinal block with the use of hypobaric solutions of local anesthetics (LA), systemic toxicity of local anesthetics, epidural hematoma and hematoma of the spinal canal, and other complications also occur in modern practice [13, 88]. At the same time, SA continues to be widely used in operations on VV of the lower extremity.

***Unilateral spinal anesthesia.***

Unilateral spinal anesthesia (USA) was first described in 1961 by Tanasichuk et al., where the authors noted less central hemodynamics and respiration disorders due to sympathetic blockade on only one side [89].

Technically, in the USA, a subarachnoid space puncture is performed with the introduction of a local anesthetic; however, unlike classical SA, the puncture occurs in the supine position, the anesthetic dose is usually reduced by 50% of the calculated dose for bilateral anesthesia. It is also obligatory to expose the patient in a lateral decubitus position for 20 minutes to achieve fixation of the anesthetic in the nerve formations of the spinal cord [25]. The rate of local anesthetic administration, its volume, type and caliber of spinal needles played an important role in the development of strictly unilateral blockade [5–7]. This type of anesthesia became widely used both in conventional medical institutions and in one-day clinics [100], due to its advantages, in particular: the achievement of an asymmetric spread of SA between the operated and non-operated sides [30], hemodynamic advantages. Thus, the

frequency of blood pressure reduction is significantly lower compared to bilateral SA and varies from 5 to 18% [1, 4, 33, 51, 72], the incidence of acute urinary retention in the postoperative period with the use of USA is significantly lower compared to conventional SA [8, 9].

Adherence to USA is caused by unilateral spread of spinal blockade, greater comfort during the postoperative period due to preservation of sensitivity and motor activity in the non-operated limb, a high rate of recovery of sensory and motor sensitivity compared to traditional SA [2, 3, 90], and high cost-effectiveness due to reducing the dose of administered anesthetic from 25 to 50% [64] and reducing the number of bed days, significantly reducing the costs of medical institutions, as well as the patients themselves for treatment [24, 58, 80].

However, in addition to all the advantages of the USA, it also has disadvantages: a high probability of damage to the roots of the spinal cord [57], deviation of the needle from the midline, unsuccessful punctures, and no leakage of CSF from the needle cannula [16]. The frequency of successful unilateral blocks varies from 13% to 94% [19, 26–28, 36, 37], which depends mainly on the qualifications of the anesthesiologist. The strict unilateral distribution of anesthetic in the subarachnoid space is not always an achievable indicator [67], it varies from 68% to 94.5%, as the location of the needle tip in the subarachnoid space is not certainly known during puncture, as the needle is inserted 'blindly'.

**Electrical nerve stimulation in regional anesthesia.**

**Spinal anesthesia with electrical nerve stimulation.**

Another continuation of SA use was the use of electrical nerve stimulation (ENS) in spinal anesthesia (SA+ENS). The purpose of developing this technique was to improve SA safety and reduce the number of puncture complications. For puncture of the subarachnoid space, needles for electrical nerve stimulation 22G and 24G, 100 mm long, and the Stimuplex HNS-12 device (B.Braun, Germany) were used. The current strength was 4ma, the pulse duration was 0.1 ms., and the pulse frequency was 2 hertz. This technique was developed to improve the safety of spinal puncture and SA and made it possible to determine the moment of dural puncture and the location of the needle tip. The use of this technique allowed the reduction of the number of unsuccessful punctures and reduction of the number of complications.

**Combined epidural-spinal anesthesia with electrical nerve stimulation (CESA+ENS) was developed based on the technique for identifying the subarachnoid space**. The essence of the method also consisted of the use of isolated needles for ENS of 22G and 24G, 100 mm long, which was first introduced into the epidural space using the resistance loss test. Next, a calculated dose of local anesthetic was injected, intended to obtain the epidural component of the anesthesia, then the needle was connected to the apparatus for electrical nerve stimulation with current strength parameters of 4 mA, pulse duration of 0.1 ms., and frequency of 2 hertz. Similarly, to the previous method, at the moment of dura puncture, a motor response was obtained in the form of muscle contractions of the lower extremities, and a flow of CSF from the needle was also obtained. Subsequently, the apparatus was turned off and 10 to 15 mg of Bupivacaine-spinal was administered to obtain the spinal component of the CESA. This technique made it possible to obtain anesthesia in duration corresponding to the duration of EA, and in terms of the quality of muscle relaxation, pain relief, and the time of onset of the corresponding SA.

**Unilateral spinal anesthesia with electrical nerve stimulation (USA+ENS)**. The basis of this method is the classic USA, but with the additional use of ENS. We used 50mm long 22G needles for electrical nerve stimulation and the Stimuplex HNS 12 apparatus (B.Braun, Germany). The patient was placed in the supine position, on the side of the intended operation. After local infiltration anesthesia of the skin with 0.5% Novocaine solution 5 ml, a Stimuplex needle connected to an electrical nerve stimulator with similar parameters of current strength 4ma, pulse duration 0.1 ms., and frequency 2 hertz was injected until the positive loss of resistance test and epidural space was reached. Next, a classic 29G size spinal needle, 90 mm long, with a Quincke cut was passed through the aforementioned needle for electrical nerve stimulation until the dura mater was punctured. Immediately after dura puncture, the current, passing through the inner wall of the needle for electrical nerve stimulation to the spinal needle, reached the subarachnoid space. This phenomenon was felt by the patient as a sensation of irritation with an electric current and immediately reported verbally to the anesthetist. The anesthesiologist also visually observed the effect of the electric current, in particular, muscle contractions of the lower limbs, depending on the strength of the current. The free flow of CSF through the spinal needle was then checked. After that, the needle cut was turned down and slowly, over 100-120 seconds, 7.5 mg of hyperbaric Bupivacaine were injected. After injection, patients were in a lateral position for 20 minutes to fix the local anesthetic on the nerve structures.

Thus, for the first time, the combination of needles for electrical nerve stimulation of the Stimuplex brand (B.Braun, Germany) was used with classical design, at the same time thin spinal needles of the Quincke type, size 29G, 90 mm long. This combination, on the one hand, makes it possible to determine the moment of puncture of the dura mater, to localize the location of the needle tip in the subarachnoid space in relation to the midline, respectively, to more accurately introduce a local anesthetic into the subarachnoid space; on the other hand, it minimizes the likelihood of complications of dural puncture in the form of PDPH.

This technique made it possible to exclude damage to the neural structures of the spinal cord, excludes multiple puncture attempts, which, in turn, reduces the incidence of PDPH with a significance level of p=0.028. Due to an additional objective criterion for dura puncture in the USA + ENS, such as muscle contractions of the lower extremities, accurate local anesthetic delivery is achieved, which, in combination with a low injection rate, improves the quality of anesthesia, expressed in Pin-Prick tests with statistical significance p= 0.018, as well as the Bromage test with p=0.014. Patient satisfaction was high, expressed as a VAS score with statistical significance p=0.02 (109).

**Conclusions**

The analysis of the literature made it possible to assess the extent of the CVI problem, details of the most effective

surgical treatments of VV in the lower extremities, and compare the advantages and disadvantages of various regional anesthesia methods and their combinations. The use of innovative approaches to improve the listed regional anesthesia methods can improve the quality of anesthesia and reduce the number of complications, both during anesthesia and in the early postoperative period. Additionally, analysis of the literature allows us to identify the most acceptable methods of anesthesia to date. For example, the use of ENS has improved the benefits of epidural, spinal, and unilateral spinal anesthesia. These advantages include the high selectivity of the blockade, the presence of objective criteria for the accuracy of the subarachnoid space puncture, the prevention of damage to the spinal cord roots, a decrease in the frequency of repeated punctures and a decrease in the number of hemodynamics, respiratory complications and the frequency of perioperative nausea and vomiting, as well as a decrease in the number of post-puncture headaches.

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***Authors' contribution:***

***Daulet Mamyrov:*** *Study concept and design;*

***Yernar Mamyrov:*** *Drafting of manuscript, and final revision;*

***Gulzhanat Jakova:*** *Acquisition of data;*

***Yoshihiro Noso:*** *Critical revision of the manuscript for important intellectual content;*

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**Корреспондирующий автор:**
**Мамыров Ернар Даулетович** – Кафедра неотложной медицины, акушерства и гинекологии, Павлодарский филиал НАО «Медицинский университет Семей», г. Павлодар, Республика Казахстан.
**Почтовый адрес:** Республика Казахстан, 140013. г. Павлодар, ул. Нуржанова 6.
**E-mail:** genius.earnico@gmail.com
**Телефон:** +77077999003, +77028998805