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ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

**OPTIMIZATION OF SPINAL ANESTHESIA IN MAJOR
JOINT ARTHROPLASTY IN ELDERLY AND SENILE
PATIENTS**

Specialty: 3231.01 – Anesthesiology and reanimatology

Field of Science: Medical Sciences

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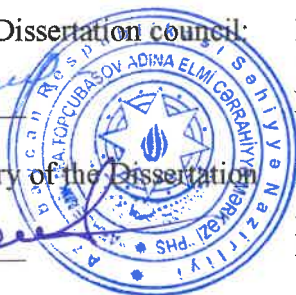
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INTRODUCTION

Relevance of the topic. One of the fundamental principles of modern anesthesiology is that, the anesthetic technique employed should provide a level of neurovegetative protection appropriate to the degree of surgical trauma while exerting minimal effects on the organs and systems of the body, preserving compensatory mechanisms and ensuring patient safety. This aspect is of paramount importance in elderly and senile individuals. Thus, age-related changes in the body, the presence of multiple comorbidities and the frequent occurrence of high sensitivity to anesthetics create severe challenges during anesthesiological support in this group of patients and must be taken into account when selecting the method of anesthesia.

Research demonstrates that, driven by the aging of the global population, the number of surgical procedures performed in elderly individuals is increasing year by year. Among these, the proportion of patients undergoing major joint arthroplasty is steadily rising, and these operations are notable for their high degree of invasiveness^{1,2}.

Currently, spinal anesthesia is primarily utilized in major surgeries performed on large joints^{3,4}.

However, the administration of local anesthetics at conventional doses is frequently associated by hypotension and bradycardia, leading to increased mortality in the elderly, whereas reducing the dosage of these drugs results in inadequate anesthesia⁵.

¹ Mohanna Maher. Safety of Anesthesia in Total Hip Arthroplasty in Elderly Patients. Abstract of Dissertation, 2010, 21 p.

² Koryachkin V.A., Liskov M.A., Maltsev M.P., Mohanna M.I. Combined Spinal-Paravertebral Anesthesia in Total Hip Arthroplasty. *Anesthesiology and Reanimatology*, 2016, No. 5, pp. 357–360.

³ Zhirona T.A., Kaikin V.A., Davydova N.S. Choice of Anesthesia Method in Hip and Knee Arthroplasty in Patients with Chronic Pain Syndrome and Psychoemotional Disorders. *Anesthesiology and Reanimatology*, 2017, No. 2, pp. 139–142.

⁴ Chapman Wei, Alex Gu, Arun Muthiah et al. Neuraxial Anesthesia Is Associated with Improved Outcomes and Reduced Postoperative Complications in Patients Undergoing Aseptic Revision Total Hip Arthroplasty. *Hip International*, 2022, March, 32(2), pp. 221–230.

⁵ Safin R.R. Clinical and Hemodynamic Characteristics of Two Anesthesia Techniques in Total Hip Arthroplasty, *Bulletin of Intensive Care*, 2008, No. 1, pp. 38–40.

For these reasons, various approaches and studies have been undertaken to improve the efficacy and safety of spinal anesthesia. It has been established that, reducing the dose of the local anesthetic is associated with a lower incidence of hemodynamic complications⁶. The simultaneous intrathecal administration of an opioid analgesic, such as fentanyl, has been shown to enhance the effectiveness of anesthesia⁷. According to some reports, the combination of spinal anesthesia with sedation using propofol provides relatively greater hemodynamic stability and improves psychoemotional comfort⁸. Incorporation of low-dose ketamine into the anesthetic regimen may further improve the quality of anesthesia⁹. A more favorable clinical course and less pronounced changes in hemodynamic homeostasis have been reported, together with a reduction in the severity, duration, and incidence of early postoperative cognitive impairment^{10,11,12}.

⁶ Ahmet Eroğlu Onal et al. Regional Anesthesia Techniques in Orthopedic Surgery. Department of Anesthesiology and Intensive Care Medicine, Karadeniz Technical University, Trabzon, Turkey. *Journal of Anesthesia & Critical Care: Open Access*, July 19, 2016.

⁷ Wang H., Peng X., Zhan L., Xiao Y., Zhao B. Effect of Intrathecal Bupivacaine and Bupivacaine Plus Fentanyl in Elderly Patients Undergoing Total Hip Arthroplasty. *Journal of the College of Physicians and Surgeons Pakistan*, 2019.

⁸ Hewson D.W., Worcester F., Sprinks J. et al. Patient-Maintained versus Anesthetist-Controlled Propofol Sedation during Elective Primary Lower-Limb Arthroplasty Performed under Spinal Anesthesia: A Randomized Controlled Trial. *British Journal of Anaesthesia*, 2022, Vol. 128, Issue 1, pp. 186–197.

⁹ Ismayilov I.S., Amrakhov V.M. Adequacy of Various Modifications of General Anesthesia Based on Ketamine. *Bulletin of Surgery of Kazakhstan*, 2014, No. 3, pp. 61–63.

¹⁰ Gemechu, A.D., Gebremedhin, T.D., Andebiku, A.A. et al. The effect of ketamine versus tramadol on prophylactic post-spinal shivering in those patients undergoing orthopedic surgery: a prospective cohort study design, *Anesthesiol*, year 2022 article number 361.

¹¹ Mostafa S.A., Mohamed G. Abo-Zeid and Omnia A. A. // The impact of ketamine on delayed neurocognitive recovery in elderly patients undergoing spinal anaesthesia for orthopaedic procedures, a pilot study, *Journal of Perioperative Practice*. 2024, Volume 35, Issue 1-2.

¹² Gilles Van de Vel, Sojeong Mun, Shahab Ud Din Zia et al. // Impact of Ketamine and Propofol on Cognitive Function in Elderly Patients: A Systematic Review, *National Library of Medicine*, 2025, Feb 16;17

Thus, in elderly and senile patients undergoing major joint arthroplasty, reduction of the bupivacaine dose during spinal anesthesia from 15 mg to 12.5 mg and the combined use of spinal anesthesia with either sedation or superficial general anesthesia appear promising. Therefore, investigation of these approaches is considered both relevant and clinically significant.

Study object and subject. The study population consisted of 115 patients, who constituted the object of the study. The subject of the study was the provision of anesthesia during major joint arthroplasty using various methods of spinal anesthesia combined with sedation or general anesthesia.

Aim of the study. The aim of the study was to comparatively evaluate the efficacy and safety of conventional spinal anesthesia and its optimized modifications in elderly and senile patients undergoing major joint arthroplasty and to determine the optimal anesthetic technique.

Objectives of the study:

In elderly and senile patients undergoing major joint arthroplasty:

1. To investigate the clinical course of conventional spinal anesthesia, its effects on hemodynamic parameters, tissue oxygenation, and selected indicators of humoral homeostasis, as well as the incidence of "critical incidents."
2. To investigate the clinical course of combined spinal anesthesia and sedation, their effects on hemodynamic parameters, tissue oxygenation, and selected indicators of humoral homeostasis, as well as the incidence of "critical incidents."
3. To investigate the clinical course of combined spinal anesthesia and superficial general anesthesia, their effects on hemodynamic parameters, tissue oxygenation, and selected indicators of humoral homeostasis, as well as the incidence of "critical incidents."
4. To identify postoperative cognitive impairment and comparatively evaluate its incidence among the study groups.
5. To comparatively assess the efficacy and safety of the anesthetic techniques used and to determine the optimal anesthetic technique.

Main provisions submitted for defense:

In elderly and senile patients undergoing major joint arthroplasty:

1. Intrathecal administration of bupivacaine at the conventional dose of 15 mg combined with fentanyl 25 μ g provides adequate analgesia; however, pronounced sympathetic blockade is associated with multiple hemodynamic "critical incidents." Emotional stress makes the use of sedative agents necessary, and cognitive impairment is observed in more than 50% of cases.
2. Combined use of spinal anesthesia based on reduced-dose bupivacaine (12.5 mg) and fentanyl (25 μ g) with propofol sedation provides psychoemotional comfort and is associated with a reduced number of "critical incidents" and cognitive impairments; however, additional analgesic supplementation is required.
3. Combined use of spinal anesthesia based on reduced-dose bupivacaine (12.5 mg) and fentanyl (25 μ g) with superficial general anesthesia using propofol and ketamine ensures greater stability of hemodynamic and humoral homeostasis and provides psychoemotional comfort. The incidence of cognitive impairment is reduced twofold.
4. Based on a comprehensive comparative assessment of the clinical course of anesthesia and the dynamics of hemodynamic and humoral homeostasis, the combined use of spinal anesthesia and superficial general anesthesia was identified as the most effective and safe anesthetic technique for this patient population undergoing arthroplasty.

Scientific novelty of the research:

1. For the first time, the efficacy and safety of three modern anesthetic techniques (conventional spinal anesthesia, and its optimized variants based on the combined application of a reduced dose of local anesthetic for spinal block with either sedation or light general anesthesia) were comparatively studied and evaluated in elderly and senile patients (age > 60 years) undergoing major joint arthroplasty.
2. Distinct clinical features of the studied anesthetic methods, specific dynamics of hemodynamic and hormonal homeostasis parameters

across the stages of analgesia, the state of tissue oxygenation, and the incidence of critical events were established. Based on these findings, the most efficient anesthetic regimen—a combination of spinal block with light general anesthesia using propofol and ketamine—was refined and validated.

3. The incidence and characteristic patterns of early postoperative cognitive dysfunction in this patient population were identified depending on the anesthetic technique applied.

Practical significance of the research. As a result of comprehensive studies, the advantages and disadvantages of three modern anesthesia techniques based on spinal blockade in elderly and geriatric patients undergoing major joint arthroplasty were identified (1 – conventional spinal anesthesia based on bupivacaine + fentanyl; 2 – spinal blockade + sedation with intravenous propofol; 3 – spinal blockade + superficial general anesthesia based on intravenous propofol and ketamine).

Through comparative complex study and evaluation, the optimal anesthetic method (combined application of spinal block and light general anesthesia) was established and recommended for clinical practice.

Implementation of the research results: The results of the dissertation have been implemented in the clinical practice of the Departments of Surgery, Anesthesiology, Resuscitation and Intensive Care of the Scientific Research Institute of Traumatology and Orthopedics.

Approbation and implementation of the work. The main results of the study were presented at the scientific conference dedicated to the 80th anniversary of Professor A.A. Akhunbayli (Baku, 2018), the 9th Çukurova Congress of Gastrointestinal Diseases (Adana, Türkiye, 2026), as well as at conferences dedicated to the 80th anniversary of Professor Ch.M. Jafarov (Baku, 2022), the 100th anniversary of the Department of Surgical Diseases III of Azerbaijan Medical University (Baku, 2022), the 90th anniversary of Professor H.A. Sultanov (Baku, 2022), and the 90th anniversary of Professor Z.A. Zeynalova (Baku, 2023). The findings were also discussed at the Congress of the Federation of Anesthesiologists and Reanimatologists of Russia (Moscow, 2025).

The preliminary discussion of the dissertation was held at a joint meeting of the Scientific Council of the Scientific Research Institute of Traumatology and Orthopedics and the staff of the Department of

Anesthesiology, Reanimatology and Intensive Care of Azerbaijan Medical University (Protocol No. 4, November 17, 2025).

The pre-defense discussion of the dissertation was held at the Scientific Seminar of Dissertation Council FD.1.12 operating under the M.A. Topchubashov Republican Clinical Medical Center, PLE (Protocol No. 1, April 25, 2026).

12 publications related to the dissertation topic have been published in journals recommended by the Higher Attestation Commission of the Republic of Azerbaijan for dissertation research. Of the 7 scientific articles, 2 were published in journals indexed in international abstracting and indexing databases. Of the 5 conference abstracts, 1 was published abroad.

The scientific findings and practical recommendations of the dissertation have been implemented in the routine clinical practice of the Department of Anesthesiology, Resuscitation, Intensive Care and Surgery of the Scientific Research Institute of Traumatology and Orthopedics under the Ministry of Health of the Republic of Azerbaijan.

Institution where the dissertation was carried out. Department of Surgery, Anesthesiology, Resuscitation and Intensive Care, Scientific Research Institute of Traumatology and Orthopedics.

Structure and volume of the dissertation. The dissertation is presented in 162 pages (203702 characters) of computer-typed text and consists of an introduction (9958 characters), a literature review (57993 characters), materials and methods of the study (20211 characters), three chapters presenting the results of the study (93632 characters), a conclusion (19017 characters), conclusions (1591 characters), practical recommendations (1300 characters), and a list of references.

MATERIALS AND METHODS

In this scientific research study, the efficacy and safety of the anesthesia techniques used in 115 elderly and geriatric patients who underwent arthroplasty procedures in the surgical departments of the Azerbaijan Scientific Research Institute of Traumatology and Orthopedics were evaluated. The findings of comprehensive clinical, laboratory, and instrumental examinations were analyzed and summarized.

A total of 115 patients included in the study were divided into three groups and followed up. Group I (control group) comprised 35 patients, Group II (first main group) comprised 40 patients, and Group III (second main group) comprised 40 patients. In 85 of these patients, comprehensive investigations were performed, and the results obtained were analyzed.

The patients ranged in age from 60 to 85 years. Their height ranged from 150 to 169 cm (mean, 158 ± 8 cm), and their body weight ranged from 54 to 114 kg (mean, 69 ± 7 kg). Of the patients, 33 (28.6%) were male and 82 (71.3%) were female.

The patients enrolled in the study predominantly suffered from gonarthrosis or coxarthrosis. The medical history revealed that the patients had undergone conservative treatment for a prolonged period (5–12 years); however, no significant positive clinical response was observed. Persistent pain syndrome resulted in the development of asthenic states, necessitating the use of analgesic and sedative medications. Accordingly, 20% of the patients (23 patients) underwent knee arthroplasty, whereas 80% (92 patients) underwent hip arthroplasty (Table 1). It should also be noted that, due to the complex anatomical structure of the ligamentous apparatus of the knee joint, knee arthroplasty procedures lasted longer than hip arthroplasty procedures. In our patients, the duration of surgery was 90–160 min (108 ± 12 min) and 55–105 min (72 ± 9 min), respectively. The majority of patients had one or more concomitant diseases. These included arterial hypertension in 64 patients (55.6%), ischemic heart disease (IHD) in 28 patients (24.3%), type 2 diabetes mellitus in 65 patients (56.5%), and a history of cerebral ischemia (ischemic attack) in 5 patients (4.3%). Patients with decompensated heart failure, hypertensive crises, severe diabetes mellitus, or significant neurological deficits were excluded from the study.

As shown in Table 1, no significant differences were observed between the groups with regard to the type of surgical procedure. It is well established that one of the fundamental aspects of anesthetic management is the accurate preoperative assessment of the patient's clinical condition and the development of an appropriate anesthetic plan.

In our practice, taking into account the duration and type of surgery, as well as the patient's condition and potential complications,

the risk level of anesthesia was determined according to the ASA (American Society of Anesthesiologists) classification (Table 2).

Table 1.

Classification of patients according to the type of surgery

Type of surgery	Patient groups			Total (n)
	I	II	III	
Hip joint arthroplasty	29 (25,2%)	28 (24,3%)	35 (30,5%)	92 (80%)
Knee joint arthroplasty	6 (5,2%)	12 (10,4%)	5 (4,4%)	23 (20%)
Total (n)	35 (30,4%)	40 (34,7%)	40 (34,7%)	115 (100%)

Table 2.

Grouping of patients according to anesthesia risk

Groups	Risk of anesthesia (according to ASA criteria)			
	I	II	III	IV
Group I (n=35)	2	24	9	-
Group II (n=40)	3	29	8	-
Group III (n=40)	-	24	16	-
Total (n=115)	5	77	23	-

As shown in Table 2, no significant differences in anesthetic risk were observed between the groups, thereby allowing for a valid comparative analysis.

Widely recognized in international clinical practice, the ASA clinical classification, encompassing these factors, plays an important role in the appropriate management of the patient's condition during anesthesia, as well as in the intraoperative and postoperative periods. Therefore, particular emphasis was placed on this classification in our study.

During the preoperative and pre-anesthetic preparation stage, all patients underwent extensive laboratory investigations, including complete blood count, biochemical blood analysis, coagulation profile, screening for common infections, and urinalysis, as well as instrumental

examinations, including chest X-ray, ECG, echocardiography, Doppler ultrasonography of the vessels of the lower extremities, and brain CT in patients with a history of traumatic brain injury or transient ischemic attack. In patients with concomitant diseases, such as arterial hypertension and diabetes mellitus, corrective medications (antihypertensive and glucose-lowering agents) were prescribed as indicated, and consultations with relevant specialists (cardiologist, neurologist, endocrinologist, and gastroenterologist) were conducted accordingly.

Immediately before surgery, the healthy lower extremity was routinely bandaged to prevent deep vein thrombosis. Peripheral venous catheterization was performed in one of the veins of the upper extremity to establish intravenous access.

Spinal anesthesia was performed with the patient in the sitting position or, in some cases, in the supine position, at the L2–L3 or L3–L4 intervertebral level. During anesthesia, humidified oxygen was administered via a face mask or nasal catheter. A vasopressor (mesatone) was administered for the prevention of arterial hypotension, while an anticholinergic agent (atropine) was administered when indicated to prevent the adverse effect of increased vagal tone on cardiac rhythm (bradyarrhythmia).

Midazolam was used for premedication in all groups at a dose of 0.05–0.1 mg/kg. During the intraoperative period, midazolam was administered intravenously in fractional doses of 5–10 mg (1–2 mL) when indicated.

Group I (control group) – observations were conducted in 35 patients, of whom 25 were included in the comprehensive study, and their results were recorded and analyzed. Among the regional anesthesia techniques, conventional spinal anesthesia was selected and administered. For this purpose, 15 mg of the local anesthetic bupivacaine was administered intrathecally together with 0.5 mL of 0.005% fentanyl, a narcotic analgesic, to enhance the analgesic effect and relatively prolong the duration of the spinal block (Table 3).

Group II (first main study group) – The study was conducted in 40 patients, 30 of whom were included in the comprehensive study. As in Group I, midazolam was administered at the conventional dose for premedication. For spinal anesthesia, the dose of bupivacaine was

reduced from 15 mg to 12.5 mg. The dose of intrathecal fentanyl remained unchanged. At the same time, during the intraoperative period, propofol was administered in fractional doses of 50–170 mg for sedation. However, additional analgesia was required due to the reduction in the bupivacaine dose. For this purpose, 0.5–1.0 mL of 0.005% fentanyl was administered intravenously in 14 patients.

Table 3.

Clinical Material (Study Population) and Anesthesia Methods Used

Groups	Anesthesia Methods Used	Medications Used
I – Control group (n=35)	Conventional spinal anesthesia	15 mg bupivacaine + 25 µg fentanyl, intrathecally
II – Main group (n=40)	Spinal anesthesia + sedation	12.5 mg bupivacaine + 25 µg fentanyl, intrathecally; propofol 50–170 mg IV
III – Main group (n=40)	Spinal anesthesia + superficial general anesthesia	12.5 mg bupivacaine + 25 µg fentanyl, intrathecally; propofol 50–100 mg IV + ketamine 0.5 mg/kg IV

Group III (second main study group) – The study was conducted in 40 patients undergoing surgery. As in Groups I and II, midazolam was administered at a dose of 0.05–0.1 mg/kg for premedication. At the same time, during the intraoperative period, in addition to propofol, ketamine was administered intravenously at a dose of 30–75 mg (0.5 mg/kg). For spinal anesthesia, 12.5 mg of bupivacaine combined with 0.5 mL of 0.005% fentanyl was administered intrathecally. During surgery, propofol 50–100 mg was administered as a bolus for sedation. In this group, the dose of propofol was reduced due to the mild analgesic, anesthetic, and amnestic effects produced by ketamine. In Group III, additional changes occurring during ketamine administration were recorded and the effect of this drug on the course of anesthesia was evaluated in comparison with the other two groups.

To evaluate the efficacy and safety of the anesthesia techniques, hemodynamic parameters were assessed at the main stages of anesthesia: Stage I – before anesthesia; Stage II – during the development of the spinal block; Stage III – after skin incision; Stage IV – during implant insertion (prosthetic replacement); Stage V – at the end of surgery; and Stage VI – during the early postoperative period, at the onset of pain. The parameters assessed included heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), systemic vascular resistance (SVR), cardiac output (CO), and stroke volume (SV). Parameters reflecting the body's oxygen supply were also evaluated, including myocardial oxygen consumption, double product (DP), respiratory rate (RR), and oxygen saturation (SpO₂).

In addition, selected indicators of hormonal homeostasis, namely serum cortisol and blood glucose levels, were measured. For the determination of stroke volume, the Starr method was used, as it demonstrated a high correlation ($r \geq 0.7$) with echocardiographic and invasive methods. HR and blood pressure (BP), as well as SpO₂, were measured using a Bionet monitor. Mean arterial pressure (MAP), systemic vascular resistance (SVR), cardiac output (CO), stroke volume (SV), and double product (DP) were calculated using established formulas. Serum cortisol and blood glucose levels were determined using modern laboratory methods.

Cases in which the studied parameters deviated by more than 20% from baseline were recorded as “critical incidents.”

The Mini-Mental State Examination (MMSE) was used to assess patients' mental status during the early postoperative period, particularly to identify cognitive impairment.

For the assessment of mental status, the questionnaire comprises five sections: A – Orientation, B – Registration, C – Attention and Calculation, D – Recall, and E – Language. The patient's performance is subsequently scored, with a maximum of 30 points. The scores were interpreted as follows: 29–30 points – no impairment, 28 points – mild cognitive impairment, 25–27 points – moderate cognitive impairment, 20–24 points – mild dementia, 10–19 points – moderate dementia, <10 points – severe dementia.

The numerical results obtained in the dissertation study were statistically processed, and reliability coefficients were determined. In

terms of design, the study was classified as controlled/cohort; by methodology, as clinical; by type, as scientific; by sample size, as sample-based; by duration, as cross-sectional and longitudinal; by material, as prospective; and by setting, as clinical.

The numerical results obtained during the study were converted to the same units of measurement and entered into a dedicated statistical database. To compare the indicators of independent groups, depending on the distribution pattern of the variation series, both parametric methods (ANOVA – Fisher's test; descriptive statistics; Student's t-test with Bonferroni correction) and non-parametric methods (Mann–Whitney U test and Kruskal–Wallis H test) were used. Comparisons of dependent groups were performed mainly using the non-parametric Wilcoxon W test.

The results of each statistical test were interpreted based on whether the null hypothesis was accepted ($p > 0.050$) or rejected ($p \leq 0.050$). Statistical calculations were performed using IBM SPSS Statistics version 26.

Results and Discussion. As shown in Table 4, in Group I, upon achieving spinal blockade, heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) decreased statistically significantly by 8.9%, 11.7%, 14.1%, and 13.0%, respectively. As can be seen, the more pronounced decrease in diastolic blood pressure is particularly noteworthy. This may be explained by total vasoplegia resulting from a pronounced sympathetic blockade, accompanied by a 15.4% decrease in cardiac output (CO) and a 19.4% decrease in stroke volume (SV). In a total of 13 patients (52%), a dynamic decrease in blood pressure exceeding 20% was directly attributable to the reduction in cardiac output. At this stage, a "critical incident" was observed in 9 patients (36%).

Another noteworthy finding was the occurrence of transient inversion of the T wave in 8 patients (32%) during the operation, which, in our opinion, was associated with arterial hypotension.

It should also be noted that bradycardia and arterial hypotension persisted and became more pronounced over time. In this regard, fluid infusion therapy in a volume of $1,625 \pm 90$ mL and Mesaton (phenylephrine) at a dose of 1.3 ± 0.3 mg were administered.

In general, psychoemotional discomfort was routinely observed in patients included in this group and was accompanied by anxiety. To alleviate these symptoms and enhance the sedative and analgesic effects, the use of propofol and/or fentanyl became necessary in a subgroup of patients (6 patients).

Table 4

Dynamics of Selected Homeostatic Parameters in Elderly and Older Patients Undergoing Major Joint Arthroplasty Surgery with Different Anesthetic Techniques

Indicator	Norm	Groups	Stages of research					
			I	II	III	IV	V	VI
HR (beats/min)	79,7 ±1,8	1	81,7±2,0	74,4±2,6 #	71,8±2,0 ###	70,6±2,8 ##	75,2±2,0 #	89,7±1,5 ##
		2	84,5±2,4	80,5±2,5	73,6±2,3 ##	70,8±2,9 ###	77,4±2,2 #	88,4±1,5
		3	86,0±3,8	79,8±4,0	75,3±4,0 ##	77,8±3,5 ##	75,3±3,6 ###	85,3±2,7
DBP (mmHg)	75,0± 2,3	1	90,3±1,8	77,6±2,6 ###	72,4±2,0 ###	70,2±2,9 ###	78,7±2,3 ###	87,8±1,6
		2	90,4±2,0	79,7±2,2 ###	74,9±1,8 ###	71,0±1,9 ###	73,9±2,0 ###	86,8±1,6
		3	89,4±3,4	84,9±3,4 ##	77,6±2,8 ###	77,2±2,7 ### *	74,3±2,3 ###	85,8±2,1
CO (L)	4,31± 0,17	1	3,66±0,20	3,75±0,18	3,87±0,20	3,79±0,18	3,87±0,20	4,26±0,20 #
		2	4,22±0,23	4,30±0,24	4,05±0,20	3,70±0,19	4,08±0,18	4,22±0,19
		3	3,71±0,25	3,82±0,31	3,80±0,32	3,93±0,35	3,80±0,35	3,75±0,32
PVR (dyn/cm²)	1705,1 ±125,9	1	2596,2 ±159,5	2195,4 ±174,7	2032,9 ±166,2 #	1935,3 ±130,2 ##	2192,4 ±159,8	2175,2 ±155,5
		2	2268,1 ±127,1	1991,4 ±110,4 ##	1992,2 ±133,4 ##	2106,8 ±179,1	1934,8 ±139,0 #	2174 ±120,0
		3	2716,2 ±257,0	2621,0 ±233,8	2654,7 ±346,2	2496,4 ±314,1	2259,0 ±236,2	2916,6 ±449,3
SV (ml)	10,13 ±0,34	1	12,25±0,5	9,88±0,50 ###	8,61±0,34 ###	8,68±0,52 ###	10,07±0,38 ###	13,11±0,1
		2	13,02±0,61	11,03±0,52 #	9,44±0,43 ###	8,29±0,46 ###	9,54±0,41 ###	12,79±0,6
		3	12,7±0,9	11,7±1,0	10,0±0,8 ###	10,1±0,7 ###	8,9±0,7 ###	12,0±0,5
Cortisol (ng/dl)	70 – 250	1						184,0±42,1
		2	334,8±64,6 327,4±34,9					178,6±39,5 #
		3	311,6±32,8					211,6±35,3 #
Glucose (mmol/L)	4,4-6,4	1	5,63±0,19					6,10±0,27
		2	6,43±0,28					6,79±0,29
		3	6,12±0,43					5,68±0,41

Note: # $p < 0.05$, ## $p < 0.01$, ### $p < 0.001$ indicate statistically significant differences compared with Stage I; * $p < 0.05$ indicates a statistically significant difference compared with Group I.

During stages III and IV of the study, a slight downward trend in systemic arterial blood pressure and Systemic Vascular Resistance (SVR) persisted; however, compared with the previous stages, this change did not differ substantially and did not reach statistical significance.

At the end of the operation (Stage V), the studied parameters remained relatively stable, although they were 10–15% lower than at baseline, which may be attributed to the strong and prolonged spinal blockade. At this stage, compared with Stage I, the blood cortisol level was 44.9% lower ($p > 0.05$), while the blood glucose level was 8.9% higher ($p > 0.05$).

Postoperative pain syndrome developed 60–90 minutes (71 ± 6 min) after surgery, while the hemodynamic parameters were comparable to those recorded at Stage I.

In patients comprising Group II, upon establishment of the spinal block, systolic arterial pressure (SBP), diastolic arterial pressure (DBP), mean arterial pressure (MAP), cardiac output (CO), and stroke volume (SV) decreased statistically significantly by 11.0%, 11.8%, 11.5%, 12.2%, and 15.3%, respectively. A decrease in arterial pressure exceeding 20% (“critical incident”) was observed in 8 patients (27%). This necessitated the administration of Mesaton (1.1 ± 0.3 mg) in combination with infusion therapy, resulting in rapid hemodynamic stabilization.

A decrease in arterial blood pressure was observed in 7 (23.3%) patients in this group and manifested as T-wave inversion on ECG, indicating a transient impairment of coronary blood flow. The condition was rapidly corrected following hemodynamic stabilization.

This abnormality resolved rapidly following hemodynamic correction.

A gradual decrease in arterial blood pressure was also observed during stages III–IV. The hemodynamic parameters were 16–27% lower than those recorded at stage I, while no significant changes were detected in the HRV and HRR parameters. Although normalization of the hemodynamic parameters under investigation was observed at the end of the operation, they did not return to their initial levels. At this stage, the serum cortisol level was 46.5% higher ($p < 0.05$), while the glucose level was 5.6% higher ($p > 0.05$) compared with stage I. The

36.3% decrease in IV during anesthesia should be considered a favorable finding in patients of this age group. However, it is noteworthy that the analgesic component had to be enhanced with fentanyl in 12 patients. In addition, against the background of hypotension and bradycardia observed in these patients, transient impairment of coronary circulation was noted; this condition resolved rapidly following hemodynamic correction.

In the early postoperative period, postoperative pain developed after 65–100 (75 ± 9) minutes, while the hemodynamic parameters differed only slightly from the levels recorded at stage I.

The findings demonstrated that in patients comprising group III, during stage II of anesthesia, systolic BP, diastolic BP, mean arterial pressure, HRV, and HR decreased by 2%, 1%, 5%, 3.7%, and 7.2%, respectively. Statistical analysis showed that these hemodynamic changes did not reach statistical significance.

At the same time, a slight upward trend was observed in the HRV and HRR parameters. During stage III of anesthesia, although a decrease in HR and arterial blood pressure was observed, the difference compared with stage I was only approximately 10–13%. During stages IV and V, the parameters differed only slightly from those recorded at stage III.

At the end of surgery and anesthesia, a decrease in serum cortisol and glucose levels of 32.1% ($p < 0.05$) and 7.2% ($p > 0.05$), respectively, was observed.

In the early postoperative period, pain syndrome developed after 80–115 (92 ± 8) minutes, while the hemodynamic parameters increased slightly and approached the levels recorded at stage I.

Comparative analysis of the comprehensive studies demonstrated that the anesthesia techniques employed—spinal anesthesia, spinal anesthesia combined with sedation, and spinal anesthesia combined with superficial general anesthesia—differed substantially in their clinical course and in the dynamics of changes in the parameters of hemodynamic and hormonal homeostasis.

Overall, all three anesthesia techniques provided adequate neurovegetative protection corresponding to the degree of surgical stress during major joint arthroplasty in elderly and geriatric patients.

The clinical signs of anesthesia and the dynamics of cortisol (Figure 1) and glucose (Figure 2) levels clearly demonstrate this effect. Furthermore, no deterioration in tissue oxygen supply was detected in any of the groups, while a notable reduction in myocardial oxygen demand was observed during the stages of anesthesia.

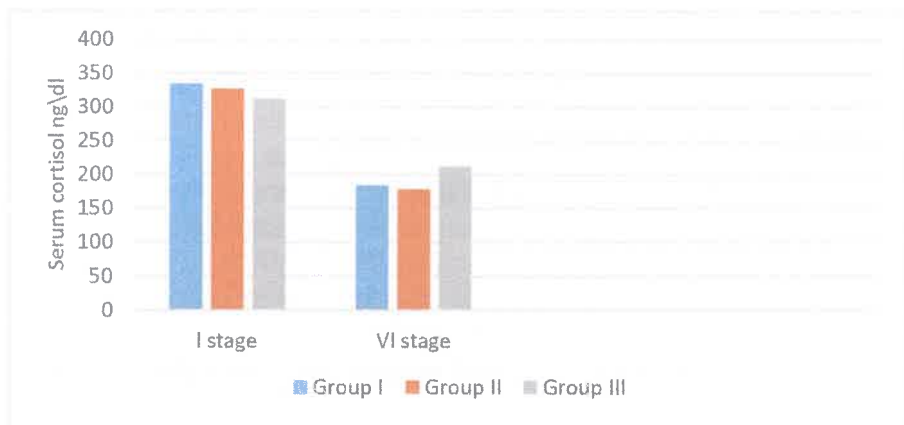


Figure 1. Dynamics of blood Cortisol levels in the Anesthesia Groups

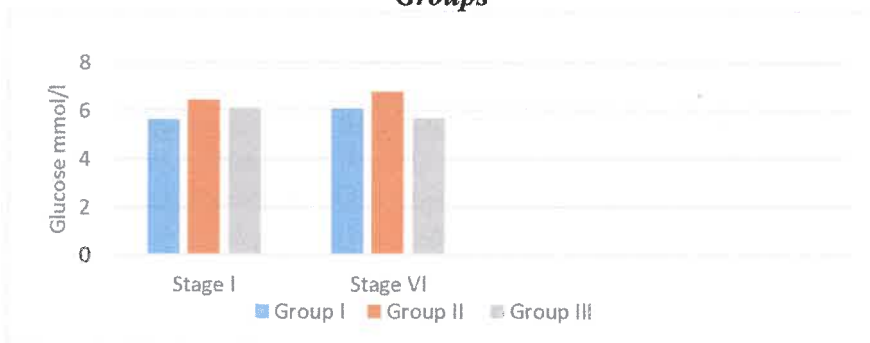


Figure 2. Dynamics of blood Glucose levels in the Anesthesia Groups

Studies have shown that although the hemodynamic changes observed during the stages of anesthesia followed the same pattern in all three groups, patients in Group I demonstrated a more pronounced decrease in arterial blood pressure, particularly diastolic blood pressure (Figure 3), as well as a greater reduction in heart rate (Figure 4).

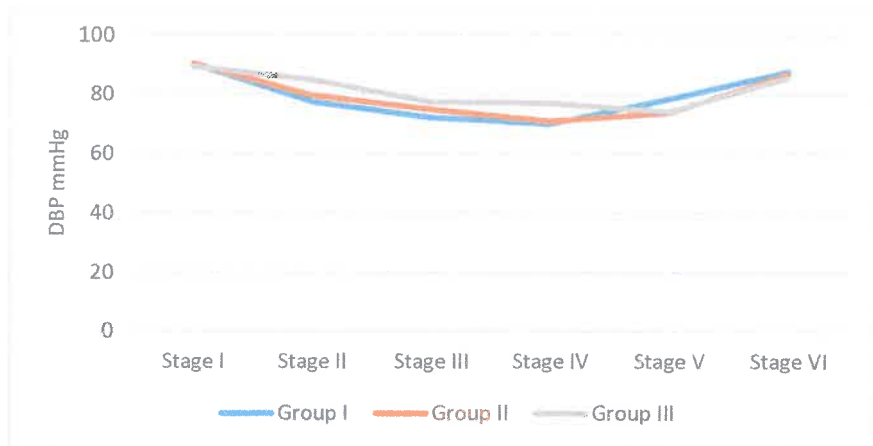


Figure 3. Dynamics of DBP in the groups I, II and III

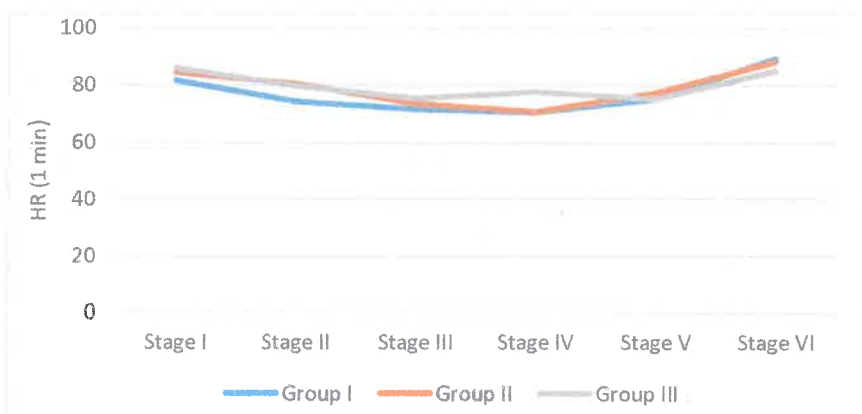


Figure 4. Dynamics of HR in the groups I, II and III

In our view, the findings described above can be attributed to the development of a pronounced sympathetic blockade following the administration of the conventional dose of bupivacaine (15 mg), resulting in a substantial reduction in cardiac output (Figure 5).

It is not surprising that, compared with Groups II and III, a greater volume of infusion solution and the sympathomimetic agent (mezafon) was administered in Group I (Table 5).

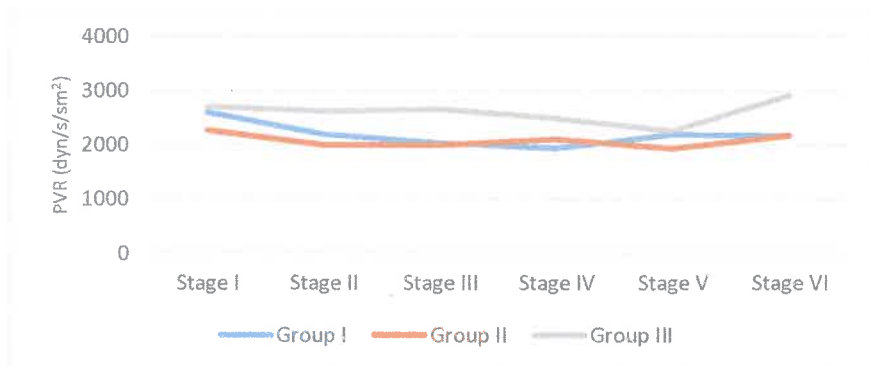


Figure 5. Dynamics of PVR in the groups I, II and III

Another noteworthy finding is that, despite active corrective measures in Group I, arterial hypotension persisted, while the tendency toward a decrease in heart rate and cardiac output observed in comparison with Stage I was maintained. It was precisely during this period that transient impairment of coronary blood flow, resembling ischemia, was observed in 32% of the patients.

Table 5.
Amounts of Infusion Solutions and Sympathomimetic Agent Administered During Different Anesthesia Methods

Groups	Infusion volume(crystalloids and colloids, ml)	Sympathomimetic agent (phenylephrine)	Blood loss
I	1625±90 ml	1,3±0,3 mq	346±32 ml
II	1550±100 ml	1,1±0,3 mq	334±26 ml
III	1200±130 ml	0,9±0,1 mq	300±50 ml

In Groups II and III, this phenomenon was observed in 23.3% and 16.7% of patients, respectively. In our opinion, intraoperative impairment of coronary blood flow may be explained by the increased susceptibility of elderly and very old patients to arterial hypotension, particularly to a decrease in diastolic blood pressure.

Nevertheless, the reduction in coronary blood flow observed in all patients was not accompanied by any clinical manifestations, and no significant ECG changes were detected during the postoperative period.

It should be noted that relative hemodynamic stability was achieved in Groups II and III by reducing the dose of bupivacaine, as well as by combining spinal anesthesia with sedation or light general anesthesia. This finding is clearly reflected in the different incidence of “critical incidents” among the groups. Although the use of propofol in Group II provided effective psychoemotional comfort, 40% of patients required enhancement of the analgesic component through the fractional intravenous administration of fentanyl. In Group III, greater and more reliable stability of the patients’ clinical condition and hemodynamic parameters was observed. The inclusion of a subanesthetic dose of ketamine in the combined anesthesia regimen provided almost complete hemodynamic stability. This finding represents a clear example of the successful combination of propofol and ketamine, which can be effectively used in elderly patients undergoing various surgical procedures.

Our study demonstrated that, cognitive disturbances (Figure 6) occurred most frequently in Group I (56%), less frequently in Group II (40%), and least frequently in Group III (30%). These disturbances were predominantly transient in nature and generally did not require any specific therapeutic intervention.

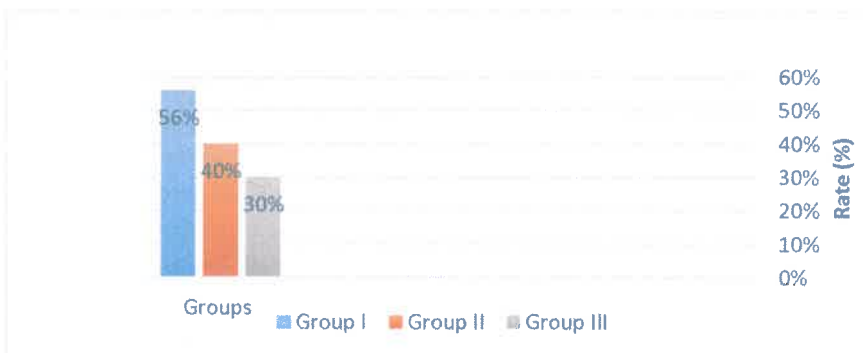


Figure 6. Frequency of cognitive disturbances during the early postoperative period

Comparative analysis between the groups revealed mild cognitive impairment in 6 patients in Group I, 4 patients in Group II, and 5 patients in Group III. During the first 24 hours after surgery, these patients demonstrated a gradually increasing reduction in

attention, impaired memory, slowed processing speed, errors in simple calculations or sequential tasks, and difficulties with planning, decision-making, and performing sequential actions. Difficulties in determining the time were particularly evident. In addition, patients experienced increased fatigue following brief conversations or activities requiring sustained attention, as well as word-finding difficulties and brief delays in responding.

Moderate postoperative cognitive dysfunction was observed in 2 patients in Group I, 5 patients in Group II, and 3 patients in Group III. The mental changes in patients with this degree of cognitive impairment were more pronounced than those observed in patients with mild cognitive impairment. A particularly notable finding was a marked deterioration in memory.

Mild dementia was identified in 3 patients in Group I, 2 patients in Group II, and 1 patient in Group III.

Moderate dementia was detected in 3 patients in Group I and 1 patient in Group II, whereas no cases of this type of cognitive impairment were recorded among patients in Group III.

When investigating the causes underlying the development of cognitive disturbances in the patient groups included in the study, we concluded that these disturbances were multifactorial in origin, involving perioperative stress, arterial hypotension, and the administration of an anticholinergic agent. Notably, cognitive disturbances occurred most frequently in Group I, in which patients experienced relatively greater psychoemotional discomfort (stress) during the intraoperative period, were exposed to arterial hypotension for a certain period, and received a higher dose of the anticholinergic agent (atropine) compared with patients in the other groups.

Recent literature has also reported that these factors play a significant role in the development of early postoperative neuropsychiatric disorders, particularly delirium^{13, 14}.

¹³ Bramley P, McArthur K, Blayney A, McCullagh I. Risk factors for Post-operative delirium: An umbrella review of systematic reviews. *IntJ Surg.* 2021 Sep; 93:106063. doi:10.1016/j.ijsu.2021.106063.PMID:34411752.

¹⁴ Zarour S, Weiss Y, Abu-Ghanim M, Iacubovici L, Shaylor R, Rosenberg O, Matot I, Cohen B. Association between intraoperative hypotension and postoperative

Finally, recent evidence indicates that advanced age itself is an independent risk factor for the development of delirium and other postoperative cognitive disturbances¹⁵. In our opinion, the occurrence of postoperative cognitive disturbances, to varying degrees, in all study groups may be explained by this factor and may, to some extent, represent an unavoidable complication. Therefore, the key approach is their timely recognition and appropriate management. It should be noted, however, that the cognitive disturbances observed in our study were generally transient in nature and did not require specific or prolonged treatment.

Thus, all three anesthetic techniques investigated in our study can be successfully used in elderly and very old patients undergoing arthroplasty. Although each technique has its own specific clinical and hemodynamic characteristics, none of them adversely affects the body's oxygen supply or compromises the relative stability of humoral homeostasis.

Finally, it should be noted that optimized spinal anesthesia (bupivacaine 12.5 mg + fentanyl 25 µg) combined with balanced superficial general anesthesia based on propofol and ketamine may be considered the optimal anesthetic approach for this patient population. This technique is characterized by minimal and clinically insignificant changes in homeostatic parameters, mild cognitive disturbances occurring in only 30% of patients, and delayed onset of the postoperative pain syndrome.

Taking the above findings into consideration, we recommend the optimized combined anesthesia technique developed in our study as the method of choice for arthroplasty procedures in elderly and very old patients.

Conclusions

1. In elderly and very old patients undergoing arthroplasty of major joints, conventional spinal anesthesia based on bupivacaine (15 mg) and fentanyl (25 µg) is associated with a profound sympathetic block, accompanied by decreases in cardiac output

delirium: a retrospective cohort analysis. *Anesthesiology*. 2024 Oct 1;141(4):707-718. doi: 10.1097/ALN.0000000000005149. PMID: 38995701.

¹⁵ Lu Y, Wang L, Wang Y, Ruan B, Lu G, Lin X. Risk Factors for Emergence Delirium in Elderly Orthopedic Patients After General Anesthesia. *Brain Behav*. 2025;15(11):e71047. doi:10.1002/brb3.71047.

(CO) of 25.5% ($p<0.01$), diastolic arterial blood pressure of 22.3% ($p<0.001$), and heart rate of 13.6% ($p<0.01$). Accordingly, a relatively high incidence (36%) of "critical incidents" requiring hemodynamic correction was recorded, while 35% of patients required the administration of sedative and, in some cases, analgesic agents [4, 11].

2. When spinal anesthesia based on bupivacaine (12.5 mg) and fentanyl (25 μ g) is combined with propofol sedation, decreases in CO of 14.7% ($p<0.05$), diastolic arterial blood pressure of 21.1% ($p<0.001$), and heart rate of 16.2% ($p<0.001$) are observed. Hemodynamic disturbances were classified as "critical incidents" in 27% of cases. At the same time, this technique provides relative stability of humoral homeostasis and the body's oxygen requirements, as well as adequate psychoemotional comfort; however, in 40% of cases, augmentation of the analgesic component of anesthesia was required [2, 5, 6].
3. Combined anesthesia consisting of spinal anesthesia (bupivacaine 12.5 mg + fentanyl 25 μ g) and superficial general anesthesia based on propofol and ketamine is characterized by a favorable clinical course, minimal changes in the studied homeostatic parameters (approximately 1–7%), which do not reach statistical significance, and a considerably delayed onset of postoperative pain syndrome [3, 8, 10].
4. Cognitive disturbances were observed most frequently in Group I (56%), less frequently in Group II (40%), and least frequently in Group III (30%). The occurrence of cognitive disturbances may be explained by the increased sensitivity of elderly patients to arterial hypotension. In particular, arterial hypotension was more frequent and persistent in Group I. Overall, cognitive disturbances in all groups were predominantly transient and did not require a specific course of treatment [7, 9].
5. Comparative analysis confirmed that all three anesthetic techniques studied provide adequate neurovegetative protection corresponding to the degree of surgical stress during major joint arthroplasty in elderly and very old patients, without evidence of impairment of myocardial functional status, humoral homeostasis, or oxygen supply to the body. Nevertheless, comparative

analysis demonstrates that the most effective anesthetic technique is the combined use of spinal anesthesia and superficial general anesthesia, which is characterized by a more favorable clinical course, greater stability of homeostatic mechanisms, and a lower incidence of cognitive impairment [8, 11, 12].

Practical Recommendations

1. Each of the three spinal anesthesia techniques—conventional and optimized—whose efficacy and safety were comprehensively evaluated in our study may be used in elderly and very old patients undergoing major joint arthroplasty, provided that specific clinical requirements are met.
2. Spinal anesthesia based on the intrathecal administration of a conventional dose of the local anesthetic bupivacaine (15 mg) and the opioid analgesic fentanyl (25 µg) may be preferable in patients predisposed to arterial hypertension and tachycardia. However, in view of the hypotension and bradycardia that may occur in the setting of a profound spinal block, more active infusion therapy and the use of sympathomimetic agents should be provided for their prevention and correction. Sedation with midazolam or propofol may also produce a beneficial clinical effect by reducing psychoemotional discomfort.
3. Analgesia based on the combined use of spinal anesthesia (bupivacaine 12.5 mg + fentanyl 25 µg administered intrathecally) and intravenous propofol sedation (1–2 mg/kg) can be successfully used in patients of this age group. However, to enhance the analgesic component, the addition of an opioid analgesic (fentanyl 0.5–1.0 µg/kg) to the anesthetic regimen is recommended.
4. In elderly and very elderly patients undergoing major joint arthroplasty, combined anesthesia based on spinal anesthesia (bupivacaine 12.5 mg + fentanyl 25 µg) and light general anesthesia (propofol 1–2 mg/kg + ketamine 0.5 mg/kg) is a clinically appropriate approach, demonstrating a favorable balance of efficacy and safety and representing an effective and safe anesthetic technique.

**LIST OF SCIENTIFIC ARTICLES AND CONFERENCE
ABSTRACTS PUBLISHED BASED ON THE
DISSERTATION MATERIALS**

1. Ismayilov I.S., Gasimov I.A., Karimli S.A. Modern Aspects of Anesthetic Management in Arthroplasty of Large Joints in Elderly and Senile Patients. Proceedings of the Scientific Conference Dedicated to the 80th Anniversary of Prof. A.A. Akhunbayli, Baku, 2018, pp. 124–127.
2. Ismayilov I.S., Gasimov I.A., Karimli S.A. Clinical and Hemodynamic Characteristics of Sedation with Midazolam Combined with Spinal Anesthesia Based on Bupivacaine and Fentanyl in Elderly and Senile Patients Undergoing Arthroplasty of Large Joints. Sağlamlıq, Baku, 2020, No. 6, pp. 67–71.
3. Ismayilov I.S., Karimli S.A. Optimization of Combined Anesthesia in Elderly and Senile Patients Undergoing Arthroplasty of Large Joints. Proceedings of the Scientific-Practical Conference Dedicated to the 80th Anniversary of Prof. Ch.M. Jafarov, Cərrahiyyə (Surgical Journal), Baku, 2022, No. 4 (1), p. 68.
4. Ismayilov I.S., Karimli S.A. Efficacy and Safety of Spinal Anesthesia Based on Bupivacaine and Fentanyl in Elderly and Senile Patients Undergoing Arthroplasty of Large Joints. Proceedings of the International Conference on “New Methods in the Diagnosis and Treatment of Surgical Diseases,” Dedicated to the 100th Anniversary of the Department of Surgical Diseases III, Cərrahiyyə (Surgical Journal), Baku, 2022, No. 4 (2), pp. 54–55.
5. Ismayilov I.S., Karimli S.A. Combined Anesthesia Based on Spinal Block and Combined Sedation in Elderly and Senile Patients Undergoing Arthroplasty of Large Joints. Proceedings of the Scientific-Practical Conference Dedicated to the 90th Anniversary of Prof. H.A. Sultanov, Cərrahiyyə (Surgical Journal), Baku, 2022, No. 4, pp. 75–76.
6. Ismayilov I.S., Gasimov I.A., Karimli S.A. Efficacy and Safety of the Combined Use of Spinal Block with Midazolam- and Propofol-Based Sedation in Elderly and Senile Patients

- Undergoing Arthroplasty of Large Joints. Azerbaijan Journal of Orthopedics and Traumatology (Special Issue), Baku, 2022, July–December, No. 2, pp. 54–59.
7. Ismayilov I.S., Karimli S.A. Characteristics of Cognitive Impairment Occurring During Combined Anesthesia in Elderly and Senile Patients Undergoing Arthroplasty of Large Joints. Proceedings of the Scientific Conference Dedicated to the 90th Anniversary of Prof. Z.A. Zeynalova, Baku, 2023, pp. 78–79.
 8. Ismayilov I.S., Gasimov I.A., Karimli S.A. Optimization of Anesthetic Management in Arthroplasty of Large Joints in Elderly and Senile Patients. Surgery Eastern Europe, 2024, Vol. 13, No. 3, pp. 441–448.
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 11. Ismayilov I.S., Karimli S.A. Selection of the Optimal Anesthesia Method in Elderly and Senile Patients Undergoing Arthroplasty of Large Joints. Sağlamlıq, Baku, 2025, Vol. 32, No. 3, pp. 85–91.
 12. Karimli S.A. Anesthetic Management Based on the Principle of Multimodality in Arthroplastic Surgery in Older Patients. Sağlamlıq, 2026, No. 3, pp. 51–52.



ABBREVIATIONS USED

1. **BP** – Blood Pressure
2. **SBP** – Systolic Blood Pressure
3. **DBP** – Diastolic Blood Pressure
4. **MAP** – Mean Arterial Pressure
5. **ASA** – American Society of Anesthesiologists
6. **DP** – Double Product (myocardial oxygen demand)
7. **KVI** – Kerdo Vegetative Index
8. **CA** – Combined Anesthesia
9. **MMSE** – Mini-Mental State Examination
10. **SA** – Spinal Anesthesia
11. **SpO₂** – Peripheral Oxygen Saturation
12. **RR** – Respiratory Rate
13. **GA** – General Anesthesia
14. **CO** – Cardiac Output
15. **SV** – Stroke Volume
16. **SVR** – Systemic Vascular Resistance
17. **HR** – Heart Rate





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