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INSTITUTIONAL EXPERIENCE WITH LAPAROSCOPIC ANTERIOR VAGINOCERVICOPEXY USING A MESH IMPLANT IN PATIENTS WITH ANTERIOR COMPARTMENT DEFECT AND APICAL PROLAPSE OF VARYING SEVERITY

ABSTRACT

Introduction. In reconstructive pelvic floor surgery using synthetic implants, several laparoscopic techniques have evolved as alternatives to sacrocolpopexy. Laparoscopic vaginocervicopexy is intended to correct apical descent together with anterior compartment failure. Since its first publication, the technique has been repeatedly modified, emphasizing the need to evaluate outcomes of different technical refinements across clinical scenarios. The aim of this study was to report a single-center experience with a modified laparoscopic vaginocervicopexy technique and to assess its effectiveness in relation to defect location and severity.

Methods. Outcomes of 137 women with apical and combined prolapse (apical defect with cystocele), including women with a preserved uterus and women after hysterectomy, operated on in 2018–2024 were analyzed. The modification included intraoperative individualization of mesh dimensions based on measured dissection length and width, followed by bilateral fixation to the aponeurosis of the anterior abdominal wall. The assessment included intraoperative and postoperative complications, recurrences, repeat surgeries, operative time, length of hospital stay, and patient-reported satisfaction measured with a standardized satisfaction questionnaire using a five-point response scale. Mean follow-up was 12.8 months.

Results. Mean age at surgery was 61.56 ± 9.59 years. The complication rate was 1.46 %, and the recurrence rate was 3.65 %. Mean operative time was 90.36 ± 14.33 minutes, and mean hospitalization duration was 52.20 ± 6.27 hours. Intraoperative blood loss did not exceed 150 mL. Patient-reported satisfaction was high, with a mean score of 4.54 ± 0.41 points, without meaningful differences across clinical groups.

Discussion. The modified laparoscopic vaginocervicopexy with individualized mesh sizing and bilateral fixation to the anterior abdominal wall aponeurosis demonstrated favorable mid-term outcomes, combining high effectiveness with low complication and recurrence rates in women with apical prolapse and cystocele.

Keywords: Pelvic Organ Prolapse; Cystocele; Vaginal Vault Prolapse; Surgical Mesh; Laparoscopy; Hysterectomy; Reconstructive Surgical Procedures; Treatment Outcome; Postoperative Complications; Recurrence.

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ВЛАСНИЙ ДОСВІД ЗАСТОСУВАННЯ ЛАПАРОСКОПІЧНОЇ ПЕРЕДНЬОЇ ВАГІНОЦЕРВІКОПЕКСІЇ СІТЧАСТИМ ІМПЛАНТОМ У ПАЦІЄНТОК З ДЕФЕКТОМ ПЕРЕДНЬОГО КОМПАРТМЕНТУ ТА АПІКАЛЬНИМ ПРОЛАПСОМ РІЗНОГО СТУПЕНЯ ВАЖКОСТІ

Вступ. У реконструктивно-пластичній хірургії генітального пролапсу із застосуванням сітчастих імплантів сформувався спектр лапароскопічних методик, що розглядаються як альтернатива сакрокольпопексії. Лапароскопічна вагіноцервікопексія спрямована на корекцію апікального пролапсу та дефекту переднього компартменту. Від моменту першої публікації ця техніка неодноразово змінювалася й удосконалювалася, що підкреслює необхідність оцінки результатів її модифікацій у різних клінічних ситуаціях. Мета дослідження – представити власний досвід застосування модифікованої лапароскопічної вагіноцервікопексії та проаналізувати ефективність методики залежно від ступеня важкості й локалізації дефекту.

Методи. Проаналізовано результати лікування 137 пацієнток з апікальним та комбінованим пролапсом (апікальний дефект у поєднанні з цистоцеле) зі збереженою маткою, а також у пацієнток після гістеректомії, прооперованих у 2018–2024 роках. Оцінювали інтра- та післяопераційні ускладнення, рецидиви, повторні операції, тривалість втручання та госпіталізації, а також суб'єктивну оцінку задоволеності хірургічним лікуванням за стандартизованим опитувальником із п'ятибальною шкалою відповідей. Середній термін спостереження становив 12,8 місяця.

Результати. Середній вік пацієнток на момент операції становив 61.56 ± 9.59 року. Частота ускладнень склала 1,46 %, частота рецидивів – 3,65 %. Середня тривалість операції становила 90,36 ± 14,33 хвилини, середня тривалість госпіталізації – 52,20 ± 6,27 години. Інтраопераційна крововтрата не перевищувала 150 мл. Середня оцінка власного стану після операції за опитувальником задоволеності хірургічним лікуванням становила 4,54 ± 0,41 бала та не відрізнялася між групами спостереження.

Обговорення. Отримані результати свідчать, що модифікована лапароскопічна вагіноцервікопексія з індивідуалізацією параметрів сітчастого імпланта та білатеральною фіксацією до апоневрозу передньої черевної стінки є ефективним і безпечним методом хірургічного лікування пацієнток з апікальним пролапсом і цистоцеле, забезпечуючи низьку частоту ускладнень і рецидивів у

середньостроковому періоді спостереження.

Ключові слова: пролапс тазових органів, пролапс вагінального купола, цистоцеле, лапароскопія, хірургічна сітка, реконструктивні хірургічні втручання, результати лікування, післяопераційні ускладнення, рецидив, задоволеність лікуванням.

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ABBREVIATIONS

LVC – laparoscopic vaginocervicopexy
POP-Q – Pelvic Organ Prolapse Quantification system
SSQ-8 – Surgical Satisfaction Questionnaire (8 items)
TVL – total vaginal length (POP-Q)
TVT-O – transobturator mid-urethral sling procedure

INTRODUCTION

Pelvic organ prolapse remains a global challenge in contemporary gynecologic surgery. When seeking solutions to this problem, we deal not only with the anatomical, physiological, and biomechanical effectiveness of surgical techniques, but also with social, aesthetic, and sexual dimensions. Addressing all these aspects determines surgical success.

The overall prevalence of pelvic organ prolapse worldwide among women ranges from 30–40 % [1, 2]. Between 1990 and 2019, the number of pelvic organ prolapse cases increased by 59.8 % [3].

Laparoscopic uterus-preserving procedures using mesh implants for pelvic organ prolapse, represented by a broad spectrum of isolated and combined techniques, have been increasingly adopted since the late 1990s [4, 5].

The use of a mesh implant with subsequent bilateral fixation to the anterior abdominal wall to correct apical prolapse and cystocele was first presented by M. Kapandji in 1967. In the late 20th century, the technique was described and refined in a laparoscopic approach by J. Dubuisson. Currently, it is widely used, including as an alternative to laparoscopic sacrocolpopexy [6,7,8].

The undeniable advantages of this surgical technique are its relative technical simplicity and high effectiveness [9, 10].

MATERIALS AND METHODS

This study analyzed the effectiveness of laparoscopic vaginocervicopexy (LVC) in women with anterior and apical compartment defects.

We assessed objective and subjective outcomes in 137 patients who underwent LVC and were followed postoperatively during 2018–2024. All procedures were performed by two expert gynecologic surgeons using an identical technique.

Mean patient age was 61.56 ± 9.59 years (range, 40–79 years).

Follow-up ranged from 4–64 months (median, 12.8 months).

All patients had a history of vaginal delivery: 17 (12.4 %) delivered once, 108 (78.8 %) delivered twice, and 12 (8.8 %) delivered three or more times.

Forty-four women (32.1 %) had undergone prior gynecologic surgery; 25 (18.2 %) of them had reconstructive procedures for prolapse, and 10 (7.3 %) had a history of cesarean delivery.

Body mass index ranged from 17.6–36.1 kg/m², with a mean value of 27.3 ± 5.6.

The prevalence of concomitant extragenital comorbidity was 88.3 % (121).

Table 1. General characteristics of the population (n = 137)

Parameter	Value
Age (years)	61.56 ± 9.59
Height (cm)	163.64 ± 5.76
Weight (kg)	74.32 ± 11.62
Deliveries	2.00 ± 0.62
Postmenopausal patients	121 (88.3 %)
Previous surgeries: - for gynecologic pathology - for pelvic organ prolapse - cesarean delivery	 44 (32.1 %) 25 (18.2 %) 10 (7.3 %)
Patients with extragenital comorbidity	121 (88.3 %)

Preoperative preparation included standard protocol-based evaluation and comprehensive assessment of pelvic organ descent using the POP-Q system.

Patients were divided into three groups according to the phenotypic characteristics of prolapse.

Group 1 included 16 (11.7 %) patients with stage II–III apical prolapse combined with stage I–II cystocele, defined by POP-Q as follows: Aa ≤ -2, Ba ≤ 1, C > 1, Ap = -3, Bp ≤ -2, TVL ≥ 9, and D ≤ -8.

Group 2 comprised 75 (54.7 %) women with stage III–IV uterine prolapse combined with stage III–IV cystocele, defined by POP-Q as follows: Aa ≤ 1, Ba > 1, C > 1, Ap ≤ -2, Bp ≤ 6, TVL ≥ 9, and D ≤ 1.

Group 3 included 46 (33.6 %) women with stage 3–4 cystocele and stage 1–2 apical prolapse, defined by POP-Q as follows: Aa ≤ 1, Ba > 1, C < -1, TVL ≥ 9, Ap = -3, Bp < -2, and D ≤ -4.

Twenty-three women (27.4 %) had a stage I posterior compartment defect without clinical symptoms.

Table 2. Population characteristics by groups

Parameters	Group 1 (n = 16)	Group 2 (n = 75)	Group 3 (n = 46)
Age (years)	54.19 ± 8.37	62.77 ± 8.81	58.89 ± 8.94
Height (cm)	164.31 ± 4.99	163.56 ± 5.63	163.23 ± 6.24
Weight (kg)	71.5 ± 9.03	74.42 ± 11.26	75.48 ± 12.41
Deliveries	2.06 ± 0.68	2.03 ± 0.64	1.91 ± 0.46
Postmenopausal patients	12 (75.0 %)	69 (92.0 %)	40 (87.0 %)
Previous surgeries: - for gynecologic pathology - for pelvic organ prolapse - cesarean delivery	 5 (31.3 %) 0 1 (6.3 %)	 26 (34.7 %) 17 (22.3 %) 5 (6.7 %)	 13 (28.3 %) 8 (17.4 %) 4 (8.7 %)
Patients with extragenital comorbidity	9 (56.3 %)	72 (96.0 %)	40 (87.0 %)

Table 3. Baseline group characteristics according to POP-Q

Parameters	Group 1	Group 2	Group 3
Aa	-2.94 ± 0.47	0.19 ± 0.91	0.91 ± 1.22
Ba	0.13 ± 1.86	2.69 ± 2.21	3.17 ± 2.09
C	3.31 ± 3.62	4.31 ± 3.24	-2.54 ± 1.16
Ap	-2.88 ± 0.50	-1.65 ± 1.71	-3.0
Bp	-2.00	-1.45 ± 1.75	-3.0
TVL	10.94 ± 1.69	10.00 ± 1.95	11.48 ± 1.52
D	-8.25 ± 1.44	-0.61 ± 2.45	-6.98 ± 2.44

Outcomes were assessed by vaginal examination on postoperative day 2 and at 2 and 12 months. Pelvic ultrasound was used as an adjunct method to evaluate vaginal wall position and mesh location at 2 months. Examinations were performed at rest and during the Valsalva maneuver. In all women, symptoms, complication rates, and recurrences were assessed in the early and late postoperative period (day 2, 2 months, and 12 months).

Patients were also surveyed postoperatively (at 2 and 12 months) using the SSQ-8 surgical satisfaction scale, where 1 point corresponded to “very unsatisfied”, 2 to “unsatisfied”, 3 to “neutral”, 4 to “satisfied”, and 5 to “very satisfied”.

Surgical Technique

After creation of pneumoperitoneum and insertion of the laparoscope through a 10-mm trocar, three 5-mm accessory trocars were placed: two laterally on both sides, 4 cm medial to the anterior superior iliac spine, and a third on the line connecting the lateral trocars, 2 cm to the right of the midline.

The uterus was grasped at the cervix with two tenaculum forceps at 7 and 11 o’clock and at 2 and 5 o’clock positions. A No. 2 uterine curette was inserted to enable anterior–posterior and lateral traction as well as rotation around the uterine axis.

The vesicouterine peritoneal fold was incised transversely along the round ligaments, starting from their bases, either from right to left or vice versa. The course of the uterine vessels and ureters was controlled bilaterally.

Dissection of the vesicocervical and vesicovaginal spaces was performed sharply and bluntly in the caudal direction down to the level of the bladder trigone. Throughout this stage, the assistant held the peritoneal leaf and bladder with an atraumatic grasper while applying traction cranially and caudally.

A key feature of our approach is intraoperative individualization of mesh dimensions. After exposing the intended fixation area, we measured the dissection length (from the proximal to the distal end) and the width of both the distal and proximal zones of the

planned mesh placement using a segment of suture material. Based on these measurements, the final mesh template was cut intraoperatively from a polypropylene mesh sheet sized 45.0 × 30.0 cm or 30.0 × 30.0 cm.

The mesh had a T-shaped configuration: the shorter central segment was used to reinforce the vaginal wall defect and fix the cervix, whereas the longer lateral arms were passed subperitoneally and sutured to the aponeurosis of the anterior abdominal wall at the lateral trocar sites.

After introducing the prosthesis into the abdominal cavity, fixation was performed using a nonabsorbable multifilament suture. In our opinion, the mandatory suture points are as follows: the apical portion (2–4 sutures), the proximal portion (3–5 sutures), and paravaginal fixation (2–8 sutures) to maintain mesh stability while simultaneously supporting the bladder pillars and the supracervical fascia. Additional fixation points can be placed as required by the clinical situation. If there is any doubt regarding the depth of vaginal wall bites, vaginal inspection after caudal traction on the tenaculum is mandatory.

The lateral arms of the mesh were externalized through the anterior abdominal wall at the lateral trocar sites. For this purpose, a retroperitoneal tunnel was created from the skin incisions to the peritoneal incision beneath the round ligament. The mesh ends were clamped, and the uterine curette and tenaculum forceps were removed.

The peritoneal incision at the vesicouterine fold was closed with a continuous 0 Vicryl suture.

After trocar removal and desufflation, we checked vaginal wall position and mesh tension. Once adequate positioning was confirmed, the lateral mesh ends were fixed to the anterior abdominal wall aponeurosis, the skin incisions were closed, and a tight vaginal tampon was placed.

Perioperative antibiotic prophylaxis was administered with cefazolin 1000 mg and metronidazole 500 mg.

RESULTS

Mean operative time was 90.36 ± 14.33 min (55–125 min). Length of hospital stay ranged from 28–57 h (mean, 52.20 ± 6.27 h). Intraoperative blood loss did not exceed 150 mL and ranged from 20–150 mL.

The intraoperative complication rate was 1.46 % (2 cases). Both events were bladder injuries in patients with a history of cesarean delivery. In both cases, the defect was sutured and the operation was completed as planned.

All patients received paracetamol infusion (500 mg) at 6, 12, 18, and 24 h postoperatively.

The Foley catheter and vaginal tampon were removed on the day after surgery.

The dimensions of the central (unpaired) portion of the mesh implant were measured and recorded intraoperatively.

Table 4. Outcomes of LVC (overall data)

Parameter	Value (n = 137)
Operative time (min)	90.36 ± 14.33
Length of hospital stay (h)	52.20 ± 6.27
Intraoperative blood loss (mL)	46,50±30,55
Intraoperative complications	2 (1.46 %)
Length of the central (unpaired) part of the mesh (cm)	8.55 ± 1.62
Width of the central (unpaired) part of the mesh (cm)	4.88 ± 0.73

Table 5. Outcomes of LVC (by groups)

Parameter	Group 1	Group 2	Group 3
Operative time (min)	87.19 ± 14.11	91.93 ± 15.01	88.91 ± 12.48
Length of hospital stay (h)	52.88 ± 5.34	52.04 ± 6.06	52.41 ± 7.14
Intraoperative blood loss (mL)	40,63±25,94	51,45±35,48	40,43±20,87
Intraoperative complications	0	2 (2.67 %)	0
Length of the central (unpaired) part of the mesh (cm)	7.25 ± 1.13	8.44 ± 1.48	9.19 ± 1.69
Width of the central (unpaired) part of the mesh (cm)	4.19 ± 0.40	4.91 ± 0.77	5.09 ± 0.59

In Group 1, within the first 2 months after surgery, complete correction of apical prolapse and cystocele was achieved. According to POP-Q, postoperative findings were: Aa = -3, Ba = -3, C ≤ -6, Ap = -3, Bp ≤ -1, TVL ≥ 9, and D ≤ -8. At 12 months, cervical elongation was observed in 3 (18.6 %) women aged 45, 42, and 40 years; point C measured -1, -1, and -2, respectively. In addition, in 3 (18.6 %) cases, a defect of the upper two thirds of the posterior compartment progressed, with Bp reaching -1 in two women and -2 in one woman. Mean SSQ-8 score at 2 and 12 months was 4.49 ± 0.40.

In Group 2 (stage III–IV uterine prolapse combined with stage III–IV cystocele), correction of uterine

prolapse and cystocele was achieved in 94.7 % (71) at postoperative day 2 and at 2 and 12 months. According to POP-Q, outcomes were: Aa ≤ -2, Ba ≤ -2, C ≤ -6, Ap ≤ -2, Bp ≤ -1, TVL ≥ 9, and D ≤ -5. At 2 months, 5 (6.7 %) women were classified as recurrence: stage II cystocele in 2 (2.7 %) cases and stage I cystocele in 3 (4.0 %) cases. These patients were asymptomatic and reported substantial improvement; therefore, no additional surgical correction was required. One case (1.3 %) of complete uterine prolapse was recorded at 2 weeks postoperatively. Relaparoscopy revealed detachment of the mesh implant from the previous fixation site; reconstructive surgery was performed with excision of the implant and placement of a new mesh, with additional correction of a paravaginal defect. At 2 months, follow-up examination and ultrasound confirmed satisfactory implant position and prolapse correction. At 2 and 12 months, an upper posterior compartment defect was noted in 14 (18.7 %) women, with Bp ranging from -1 to -2. At the 2-month visit, 8 (10.7 %) patients reported episodes of urinary leakage during physical exertion, sneezing, or coughing. Three women (4.0 %) reported occasional preoperative leakage with abrupt rises in intra-abdominal pressure but declined concomitant incontinence surgery because symptoms were mild. After LVC, increased symptom frequency required TVT-O in 3 (4.0 %) cases at 12 months. Over 1 year, cervical elongation was observed in 3 (4.0 %) women aged 45, 44, and 43 years. Mean SSQ-8 score at 2 and 12 months was 4.52 ± 0.42.

In Group 3 (preoperatively: stage 3–4 cystocele and stage 1–2 apical prolapse), 12-month follow-up demonstrated no signs of apical defect or cystocele. According to POP-Q: Aa ≤ -3, Ba = -3, C ≤ -6, TVL ≥ 9, Ap = -3, Bp < -3, and D ≤ -7. Mean SSQ-8 score at 2 and 12 months was 4.59 ± 0.40.

Table 6. Postoperative POP-Q status (12 months)

Parameters	Group 1	Group 2	Group 3
Aa	-3.0	-2.32 ± 0.62	-3.0
Ba	-3.0	-2.19 ± 1.15	-3.0
C	-7.31 ± 2.73	-7.81 ± 2.32	-7.30 ± 1.21
Ap	-3.0	-2.33 ± 0.47	-3.0
Bp	-2.69 ± 0.70	-2.08 ± 1.18	-3.0
D	-8.25 ± 1.44	-6.45 ± 1.55	-8.72 ± 1.31
TVL	10.56 ± 1.75	11.93 ± 1.54	11.54 ± 1.63

Table 7. Dimensions of the central (unpaired) part of implanted meshes

	Overall	Group 1	Group 2	Group 3
Length (cm)	8.55 ± 1.62	7.25 ± 1.13	8.44 ± 1.48	9.19 ± 1.69
Width (cm)	4.88 ± 0.73	4.19 ± 0.40	4.91 ± 0.77	5.09 ± 0.59

All women resumed physical and sexual activity 2 months after surgery.

The most common complaint was discomfort and moderate pain at the site of mesh fixation to the aponeurosis (lateral trocar sites), which lasted up to 46 postoperative days in 64 (46.7 %) patients.

No complications related to urination or defecation were recorded.

Table 8. Surgical satisfaction assessment (SSQ-8)

Group	Group 1	Group 2	Group 3
Result	4.49 ± 0.40	4.52 ± 0.42	4.59 ± 0.40

No cases of mesh erosion were observed.

In 99.2 % of cases, dynamic ultrasound assessment of implant position (on postoperative day 1 and at 2 months) showed no change in mesh location.

DISCUSSION

Analysis of operative outcomes and follow-up data allows several important aspects of applying laparoscopic vaginocervicopexy in women with apical prolapse and cystocele of varying severity to be highlighted.

Women aged 40–45 years constituted 8.0 % (11) of the total cohort. Cervical elongation during follow-up was documented in 6 (54.5 %) of these patients. Although the sample size is insufficient to draw statistically robust conclusions, this finding warrants attention and further analysis and may indicate age-related sensitivity of LVC outcomes in reproductive-age women. In our view, a combined procedure – laparoscopic supracervical hysterectomy with vaginocervicopexy – may help avoid complications related to cervical elongation. Alternatively, the

proposed technique can be combined with cervical amputation in patients with pre-existing elongation.

The development and progression of urinary incontinence symptoms in 10.7 % of patients with severe combined prolapse underscores the importance of preoperative screening for occult incontinence and the potential need for concomitant anti-incontinence correction during LVC. We have experience performing TVT-O and Burch colposuspension concomitantly with LVC; this analysis is currently ongoing.

Enterocele occurred in 12.4 % (17) of cases at 2 and 12 months after surgery. This feature of LVC has been described previously [11, 12]. We believe that concomitant laparoscopic midline plication of the uterosacral ligaments and the rectovaginal fascia may be an effective method for preventing this defect.

CONCLUSIONS

LVC is an accessible, standardized surgical approach to eliminate apical defect and cystocele, with a high success rate.

Our study demonstrated effectiveness in correcting apical prolapse and cystocele regardless of their stage and localization.

Complete anatomical correction of anterior and apical defects, based on examinations at 2 and 12 months, was achieved in 98.2 % of women. Group-specific success rates were: Group 1, 100 %; Group 2, 94.6 %; Group 3, 100 %. Postoperative POP-Q parameters describing the anterior and apical compartments were as follows:

Group 1: Aa = -3.0, Ba = -3.0, C = -7.31 ± 2.73;

Group 2: Aa = -2.32 ± 0.62, Ba = -2.19 ± 1.15, C = -7.81 ± 2.32;

Group 3: Aa = -3.0, Ba = -3.0, C = -7.30 ± 1.21;

Mean postoperative SSQ-8 score was 4.54 ± 0.41 and did not differ significantly across groups.

The question of isolated use of LVC remains open in cases of pelvic organ prolapse involving rectal descent (posterior compartment involvement) and in women with stress urinary incontinence symptoms. In such settings, a combined surgical strategy appears reasonable. For posterior compartment defects, laparoscopic midline plication of the uterosacral ligaments and the rectovaginal fascia during LVC may be considered; alternatively, a combined approach can be used with laparoscopy to correct apical and anterior prolapse and a vaginal approach to address rectocele. In women with diagnosed stress urinary incontinence, TVT-O may be considered as a first-line surgical option and the Burch procedure as a second-line option.

A detailed analysis of the anatomic and topographic features of prolapse enables selective choice of surgical technique and maximizes effectiveness.

The data obtained in this study motivate further analysis and investigation.

PROSPECTS FOR FUTURE RESEARCH

Further studies should focus on long-term anatomic and functional outcomes of the technique, risk factors for recurrence, and comparisons with alternative laparoscopic approaches in standardized cohorts.

ETHICAL CONSIDERATIONS

The study adheres to the basic provisions of ICH GCP (1996), the Council of Europe Convention on Human Rights and Biomedicine (April 4, 1997), the World Medical Association Declaration of Helsinki “Ethical Principles for Medical Research Involving Human Subjects” (1964–2013), the Order of the Ministry of Health of Ukraine № 281 of November 1, 2000, and the Ethical Code of the Scientist of Ukraine (2009). The study was approved by the Bioethics Commission of Odesa National Medical University (Protocol № 11, March 6, 2023).

AUTHOR CONTRIBUTIONS

Concept and design of the study: [Chekhanov Yu.O., Gladchuk I.Z.].
Data collection: [Chekhanov Yu.O., Chekhanov O.Yu.].
Data analysis and interpretation: [Chekhanov Yu.O., Gladchuk I.Z.].
Manuscript drafting: [Chekhanov Yu.O., Chekhanov O.Yu.].
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The authors have no conflict of interest to declare.

ARTIFICIAL INTELLIGENCE DISCLOSURE

The authors declare that artificial intelligence tools were used solely for language editing and stylistic improvement of the manuscript. No artificial intelligence was used for data generation, statistical analysis, or interpretation of the results. All scientific content and final editorial decisions were made by the authors, who take full responsibility for the integrity and accuracy of the work.

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