



Original Article

Anatomical CT study of lumbar artery perforator flap in women

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ABSTRACT

Background: The lumbar artery perforator (LAP) flap is an important autologous option in breast reconstruction. As the lumbar perforator flap is relatively new in this field, several questions remain regarding preoperative preparation, especially concerning computed tomography (CT) and magnetic resonance imaging of the donor site. The objective of this study was to aid the surgical approach to the LAP flap in female patients by precisely determining the characteristics of the lumbar perforators.

Methods: We retrospectively reviewed the computed tomographic angiography images of 20 patients who underwent evaluation of the perforator positions from the four lumbar arteries. Four characteristics were studied: length, diameter, path of the lumbar pedicle, and thickness of the tissues available for transfer.

Results: We analyzed 20 CT images, identifying 149 perforating vessels of the lumbar artery. The most suitable perforator for flap harvesting was the L4 perforator, which exhibited a larger diameter, a greater number of perforasomes, and a higher percentage of the cutaneous-septal tract.

Conclusion: The LAP flap is a viable option for breast reconstruction and as a free flap in women. The L4 perforator artery is the most suitable for harvesting, owing to its superior perfusion capacity, diameter, and course; however, an interposition graft may be required to lengthen the vascular pedicle.

1. Introduction

The use of autologous breast reconstruction continues to evolve. Most advances focus on reducing complications following reconstruction, shortening recovery time, and improving the aesthetic outcomes of both the donor and recipient sites. A significant portion of the literature is devoted to the abdominal perforator flap, specifically the deep inferior epigastric perforator (DIEP).^{1,2} As autologous reconstruction progresses, other alternative flaps have emerged, offering a more tailored approach to donor site selection for individual breast reconstructions.³ The lumbar artery perforator (LAP) flap has become an additional option for breast reconstruction.⁴ Many patients who have undergone cosmetic abdominoplasty possess sufficient skin and subcutaneous fat in other donor areas, making the LAP flap an excellent option in these cases. Furthermore, as experience has accumulated and new modified techniques have been developed, the success rates of the LAP flap have approached those

of other commonly performed autologous breast reconstruction methods.⁵

The history of the lumbar flap dates back to 1978, when Hill et al.⁶ described a transverse lumbosacral flap supplied by axial proximal vessels and dermal blood supply for treating sacral defects. In a retrospective study, the use of this flap in 20 patients was evaluated, concluding that the flap is applicable for the treatment of sacral pressure ulcers. However, the authors did not detail the axial structure and dimensions of the flap. In 1988, Kroll and Rosenfield⁷ first described this flap, calling it “innocent,” to address a defect in the lower back along the midline. In 1999, Kato et al.⁸ illustrated the anatomical features of the flap and conducted a cadaveric study of the lumbar region. Subsequently, Weerd and Weum⁹ reported the successful creation of a double “butterfly” flap, which was used to cover a large sacral defect while preserving sensation. In 2007, Sommeling¹⁰ identified the L3 and L4 perforators as dominant, with a consistent location, which could be tracked using Doppler ultrasound.

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The LAP flap was first used in breast reconstruction in 2003 but remained underutilized due to the long dissection process. In 2015, Peters¹¹ described the LAP flap as a viable alternative for autologous breast reconstruction in asthenic patients who had undergone abdominoplasty. There have been few anatomical studies of the LAP flap since its initial description in 1987.¹² At least six studies have detailed the anatomy of the lumbar flap, combining preclinical cadaveric imaging with vascular bed imaging and clinical application to describe the radiographic and surgical aspects.

To optimize the reconstruction process, preoperative mapping of the lumbar arteries (LA) and their perforators is essential. This mapping aids in the efficient reconstruction of the mammary gland using the LAP flap by predicting the exit points of the perforators. Such mapping helps facilitate the isolation of the vascular pedicle and provides a predictable course during the microsurgical stage, reducing operation time and minimizing the risk of postoperative complications. Various imaging methods, including magnetic resonance angiography (MRA), contrast-enhanced ultrasound, and color Doppler mapping, are used for this purpose.^{13–15} However, the “gold standard” among these methods is computed tomography angiography (CTA), which provides greater specificity and sensitivity in visualizing perforators and is more widely accessible for radiation diagnostics. In this context, the objective of this study is to evaluate the capabilities of CTA in preoperative mapping to identify the lumbar artery and its perforators when planning surgery involving the LAP flap.

2. Material and methods

2.1. Study characteristics

This retrospective analysis included patients who underwent DIEAP flap reconstruction in 2024. The parameters of the 158 LAs visualized during 20 CTAs in patients who underwent CT of the aorta and its branches were evaluated. The results are presented in Table 1. Inclusion criteria were as follows: age ≤75 years; a body mass index (BMI) between 20 and 30; absence of aortic pathology (e.g., aortic prosthesis, aneurysm with false lumen); and absence of bone deformities in the pelvis or lumbar spine (Table 1).

2.2. LA characteristics

The results of 20 CT scans of the abdominal aorta and its branches were analyzed using a dual-tube CT scanner (Somatom Drive, Siemens, Germany) with the DS AngioRunoff scanning protocol (Eff mAs 120; kV 80; slice thickness 0.6 mm). The study was performed in the craniocaudal direction (from the level of the L2–L3 vertebral bodies to the level of the femoral heads). Bolus intravenous contrast administration was performed with iogexol (350 mg of iodine per 100 mL) through the cubital vein in a volume of 60–100 mL. The contrast agent was administered at a rate of 4–5 mL/s using a two-bulb automatic injector (Medrad, Bayer, Germany); the second bulb was used for the intravenous administration of 40–50 mL of physiological solution to improve contrast. The slice thickness was 0.6 mm, and the radiation exposure ranged from 2.2 to 11.0 mSv. For CTA image analysis, the DICOW-viewer OsiriX MD in 3D MPR (CT-Abdomen) mode was used, focusing on the arterial phase. In the sagittal and axial slices, the course of the lumbar arteries at the level of the L1–L4 vertebrae was traced. These arteries give rise to perforators within the lumbar muscles, including the quadratus lumborum and back

extensors. The diameter of the perforators was measured at the point where they exit the muscle into the lumbar fascia, using the “Length” tool to measure the distance between the vessel walls.

Given that L4 perforators were most commonly used in the literature, the primary focus was on evaluating the parameters of the L4 perforators. The following characteristics were evaluated: (1) lumbar artery perforators, (2) course of the perforators, (3) diameters of L4 perforators, (4) correlation between the L4 diameter and perforator diameter, and (5) perfusion capacities of the L3 and L4 perforators.

2.3. Statistical analysis

Statistical analysis was performed using Statistica 10 (Statsoft Inc.). Proportions and frequencies (%) were calculated for categorical parameters, and contingency tables were used to compare differences between groups and determine correlations between the assessed criteria. The Spearman’s rank correlation test was used (considered statistically significant if $P<0.05$), and the Wilcoxon nonparametric test (considered statistically significant if $P>0.05$).

3. Results

Twenty female patients aged 38–56 years (mean: 47 years) with a BMI between 20 and 30.5 kg/m² (mean: 25.8 kg/m²) were studied. Their heights varied between 157 and 178 cm (mean: 167.5 cm). Out of the 40 hemi-bodies, 38 third lumbar arteries (L3) and 48 fourth lumbar arteries (L4) were analyzed. The vessels that were not consistently visualized throughout their lengths were excluded. The dominant LAPs were derived from the L3 and L4 arteries in 88% of cases (Figs. 1 and 2).

The established parameters of 149 perforators visualized during 20 computed tomography angiography (CTA) scans were assessed. Among them, 20 perforators (13%) followed the septocutaneous pathway, whereas 129 perforators (87%) followed the musculocutaneous pathway. The obtained results are presented in Table 2.

We determined the septocutaneous and musculocutaneous characteristics of the LAPs. Most perforators followed an intramuscular pathway. Of all the perforators, the L1 perforator had a septocutaneous course in only one case, the L2 perforators had a septocutaneous course in three cases, the L3 perforators had a septocutaneous course in three cases, and the L4 perforators had a septocutaneous course in 13 cases. Table 3 summarizes the numbers of musculocutaneous and septocutaneous perforators. A trend was observed, where, moving from the L1 to the L4 level, the course of the perforators shifted from musculocutaneous to septocutaneous. The largest number of septocutaneous perforators was observed at the L4 level.

We conducted a targeted assessment of the L4 perforators, studying 48 L4 LAPs, determining their minimum and maximum diameters, calculating their average diameters, and measuring the distance from their exit point at the psoas muscle to the L4 spinous process. Summary data are presented in Table 3.

We also assessed the correlation between the diameter of the L4 LAP and the diameter of its perforators. Among the 20 CTA patients, a correlation analysis was carried out between the diameters of the L4 artery and its perforators. In some cases, we observed an anatomical feature where certain perforators had a larger caliber than their main trunk vessels. This was not related to the overlay of the arterial and venous phases, as we separated their demonstrations. The results are presented in Table 4 and Fig. 1.

We analyzed data from 34 LA-4 to 48 perforators, determining the diameter of each patient’s LA-4 and the average diameter of the perforators on each side. A correlation analysis was performed using Spearman’s test, revealing a weak inverse relationship between the diameter of LA-4 and the average diameter of its perforators (Table 2). The Spearman correlation coefficient (ρ) was -0.158 , indicating a weak relationship according to the Chaddock scale. The degrees of freedom (f) were 27, and the critical value of the Spearman criterion for this number of degrees of

Table 1
Lumbar artery characteristics.

Characteristic	Diameter (mm)
Minimum value	1.52
Maximum value	3.29
Median ± standard deviation	2.06 ± 0.35

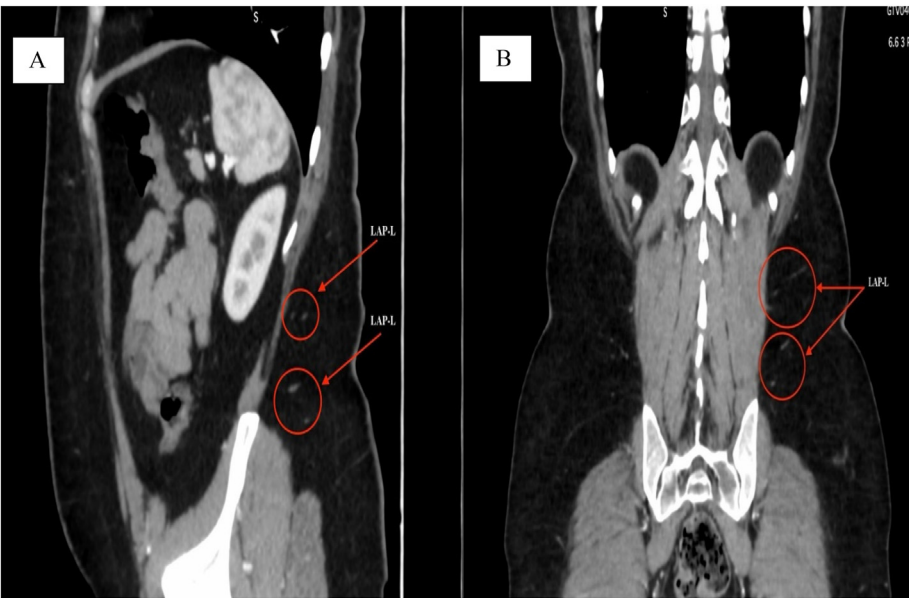


Fig. 1. (A) Computed tomography images of the lumbar region showing perforators of the lumbar artery in the frontal section. (B) Computed tomography images of the lumbar region showing perforators of the lumbar artery in the sagittal section.

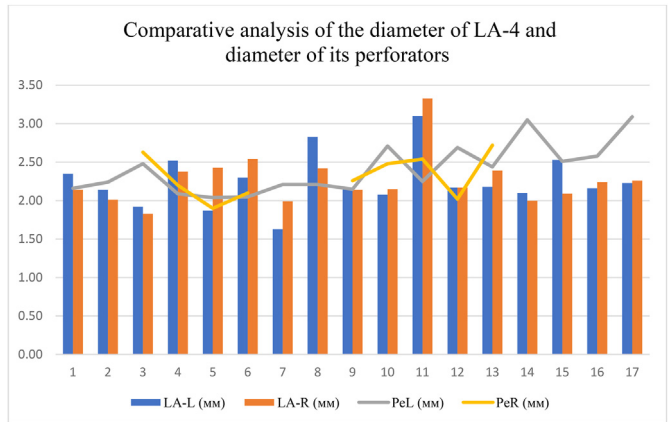


Fig. 2. Comparative analysis of lumbar artery-4 diameter and perforator diameter.

Table 2
Characteristics of lumbar artery perforators: diameter and distance to the spinous process of L4.

Characteristic	Diameter (mm)	Distance to spinous process L4 (cm)
Minimum value	1.57	0
Maximum value	3.49	13.26
Median ± standard deviation	2.24 ± 0.39	7.84 ± 0.39

Table 3
Characteristics of lumbar artery perforators: number of lumbar artery-4 perforators and their diameter.

Characteristic	Diameter (mm)	Distance to spinous process L4 (cm)
Minimum value	1.81	0
Maximum value	3.49	13.26
Median ± standard deviation	2.27 ± 0.33	7.61 ± 1.85

Table 4
Comparative analysis of lumbar artery diameter and perforator diameter.

Patient no.		LA-4 diameter (mm)	Diameter of perforators (mm)	Spearman's correlation test (p)
1	Right	2.14	2.02	−0.158
	Left	2.35	2.16	
2	Left	2.14	2.24	
3	Right	1.83	2.63	
	Left	1.92	2.48	
4	Right	2.38	2.20	
	Left	2.52	2.09	
5	Right	2.43	1.90	
	Left	1.87	2.04	
6	Right	2.43	1.90	
	Left	1.87	2.04	
7	Right	2.54	2.10	
	Left	2.30	2.05	
8	Left	1.63	2.21	
9	Left	2.83	2.21	
10	Right	2.14	2.26	
	Left	2.17	2.15	
11	Right	2.15	2.48	
	Left	2.08	2.71	
12	Right	3.33	2.54	
	Left	3.10	2.25	
13	Right	2.17	2.02	
	Left	2.17	2.69	
14	Right	2.39	2.72	
	Left	2.18	2.44	
15	Left	2.10	3.05	
16	Right	2.09	2.32	
	Left	2.53	2.51	
17	Right	2.26	2.27	
	Left	2.23	3.09	

freedom was 0.368. Since p (observed) $< p$ (critical), the dependence is not statistically significant ($P > 0.05$). The perfusion capacities of the LA-3 and LA-4 perforators were assessed by evaluating the branching and localization of the lumbar artery perforators in the subcutaneous adipose tissue. The perfusion capacity was determined using the Perfusion CLUT tool (Color Look-Up Tables) in the OsiriX DICOM-viewer. A large blood supply area indicates a larger perforasome. The results are shown in Fig. 3.

Among the 20 patients who underwent CT angiography of the aorta

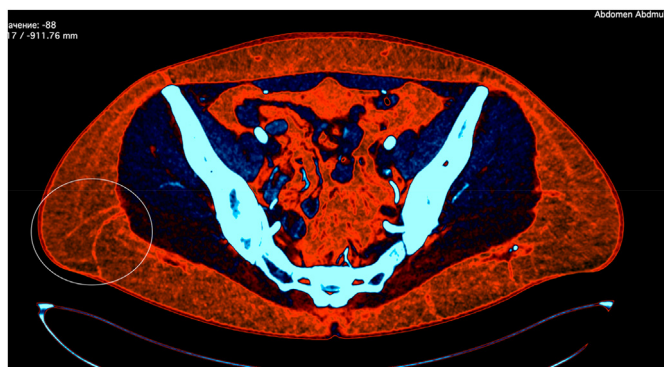


Fig. 3. Perfusion CLUT tool (Color Look-Up Tables). Lumbar artery perforator bifurcation and its perforasome.

and its branches, 40 LA-3 and LA-4 perforators were evaluated, and their perfusion capacities were assessed. Of these, 14 perforators (35%) were classified as LA-3, while 26 perforators (65%) were classified as LA-4. We calculated the incidence of LA-3 and LA-4 perforators in patients with large perforasomes, concluding that the LA-4 perforators have the greatest perfusion capacity. Based on data from 20 CTA patients who underwent breast reconstruction using an LAP flap, volume rendering technique (VRT) reconstruction was performed using the Synga workstation, and three-dimensional images of the LA-3 and LA-4 perforators were obtained (Figs. 4 and 5).

4. Discussion

The localization of LAPs has been extensively discussed in the literature; however, several unresolved questions remain regarding preoperative imaging using CTA for breast reconstruction. In addition to CTA, multiple studies have described the use of MRA for preoperative mapping.^{16,17} Both CTA and MRA significantly enhance the overall safety of intraoperative surgical flap extraction, reduce operation time, and decrease the risk of postoperative complications. MRA is generally preferred over CTA in many cases due to the absence of radiation exposure, superior visualization of the intramuscular perforator passage, and the absence of iodinated contrast. When MRA is unavailable or contraindicated, CTA, which is widely available, can provide similar information, and surgeons and radiologists worldwide are more familiar with this technique.¹⁸ In the study by Cina et al., the results of preoperative marking of perforators in the CTA and MRA groups were compared: the accuracy of identifying dominant perforators was 91.3% for both groups, and the standard error in measuring their diameters was 1.18 (± 0.35) mm for the CTA group and 1.63 (± 0.39) mm for the MRA group.

CTA has been the examination of choice for the anatomical study of LAPs. However, it has some technical limitations, such as the delayed acquisition of images in the arterial phase, the presence of artifacts, and insufficient resolution for the accurate measurement of small vessels (<1.5 mm).

In our study, 20 CT images of the lumbar region were analyzed. According to the assessment of the diameters of the lumbar artery perforators, there was a tendency toward an increase in the diameter of perforating arteries 3 and 4. The largest diameter of the perforating artery was found at L4 (3.49 mm), which correlates with data from other authors. Interestingly, when assessing the course of lumbar artery perforators, only 13% had a cutaneous-septal course, and most perforators with a cutaneous-septal course were L4 perforators. When comparing the diameters of the lumbar artery and its perforators at the L4 level, a weak relationship was observed. According to perfusion capacity, the L4 perforator also had a greater number of perforasomes (26%). The course of the lumbar artery perforators, the comparative analysis of the

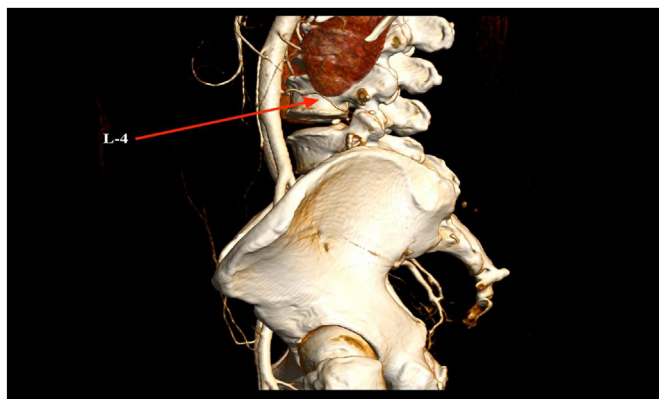


Fig. 4. 3D volume rendering technique reconstruction (sagittal view) showing L4, the fourth lumbar artery.

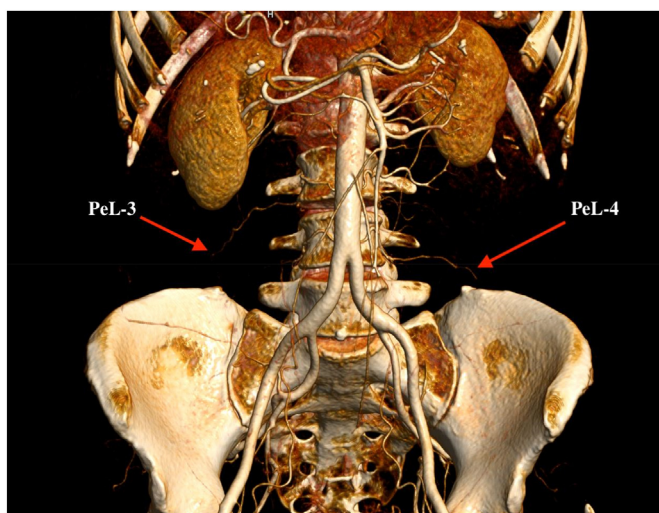


Fig. 5. 3D volume rendering technique reconstruction (frontal view) showing PeL-3 (perforator artery of the lumbar artery) and PeL-4 (perforator artery of the 4th lumbar artery).

diameters of the lumbar artery and its perforators at the L4 level, and the L4 perforator's perfusion capacity have not been previously described. The perforator mapping protocol was modified using the L4 spinous process as a reference point, and 3D models of the vessels with cinematic rendering techniques were created to facilitate preoperative patient marking for surgeons. To accurately perform body-surface localization of the LAP vessels, two anatomical landmarks are essential: the posterior midline, corresponding to the spinous processes of the vertebrae, and the posterior aspect of the iliac crest, which can be identified through palpation. Using these two landmarks, the trajectory of the perforating vessels in the lumbar region can be delineated using a centimeter ruler and a marking instrument. Precise mapping is crucial for ensuring appropriate surgical planning and intervention in procedures involving LAP perforators.

In 1999, Kato¹⁹ was the first to study the lumbar region using cadavers. In 2020, Thomas et al. conducted a study on men and concluded that there were no differences in the location of perforators between men and women. Our study analyzed 20 CT images of the lumbar region. The assessment of the diameters of the lumbar artery perforators revealed a tendency for an increase in the diameter of perforating arteries 3 and 4. The largest perforating artery diameter was found at L4 (3.49 mm), which aligns with data from other authors. Interestingly, when assessing the course of lumbar artery perforators, only 13% exhibited a cutaneous-septal course, with the majority being L4 perforators. A weak

correlation was observed when comparing the diameters of the lumbar artery and its perforators at the L4 level. Additionally, in terms of perfusion capacity, the L4 perforator had a greater number of perforators (26%). Our data support the widely accepted notion that the lower lumbar vessels give rise to more and slightly larger perforators (L3 and L4 perforators were dominant in 87% of patients). The main disadvantage of LAPs is the short pedicle.²⁰ Our results confirmed that the lower the LAP on the abdomen, the shorter the vascular pedicle, with the dominant perforators having a mean length of 6.5 cm in our series. Therefore, grafts are often necessary. In 57% of flap reconstructions, Hamdi et al. required an interposition graft from the lower epigastric vessels, while Peters et al. required an interposition graft in 77% of cases.²¹ In most instances, all authors used an interposition graft to lengthen the vascular pedicle.

It is crucial for surgeons to recognize that the shape of the reconstructed breast is primarily determined during flap harvesting. The firmness of lumbar soft tissue limits its adaptability, making it less conducive to the intricate folding and shaping possible with other flaps, such as the DIEP flap. Therefore, careful and strategic planning during flap harvesting is essential to achieve a final breast shape that aligns with both aesthetic and reconstructive goals. The unique properties of lumbar tissue require a thoughtful approach, as its limited postharvest malleability can significantly affect the outcome of reconstruction. The LAP flap has gained recognition as a promising option for breast reconstruction, particularly in cases where traditional donor regions, such as the DIEP flap, are unsuitable or unavailable. In such cases, the LAP flap serves as a reliable and effective alternative. Furthermore, many patients who undergo cosmetic abdominoplasty experience residual truncal fullness, which may lead to dissatisfaction. In these cases, the LAP flap provides an excellent solution, addressing both aesthetic and functional needs.

5. Conclusion

The LAP flap is currently the preferred option for patients who are not candidates for DIEP flap reconstruction. Based on the results of our study, the most favorable anatomical feature is the lumbar flap based on the perforator vessels of the 4th lumbar artery. The study demonstrated the potential of using CTA with 3D reconstruction to study the variable anatomy of the lumbar artery and LAP for preoperative mapping. However, the study has limitations, including the lack of intraoperative anatomical validation. The quality and volume of lumbar fat around the iliac crests allow for bilateral autologous reconstruction, even in thin patients. Further studies are needed to identify the optimal insert for lengthening the flap's vascular pedicle and improving surgical outcomes.

CRediT authorship contribution statement

Olesya Startseva: Supervision, Resources, Methodology, Investigation. **Igor Reshetov:** Supervision, Resources, Funding acquisition. **Jaume Masia:** Methodology, Conceptualization. **Alexandra Frolova:** Writing – original draft, Validation, Investigation, Funding acquisition. **Elena Merzhina:** Supervision, Project administration, Methodology, Investigation. **Evgeniya Zhigailova:** Visualization, Validation, Formal analysis. **Mark Gabriyanchik:** Writing – review & editing, Supervision, Project administration, Investigation, Data curation.

Ethics approval and consent to participate

This study was approved by the Institutional Ethics Committee of I.M. Sechenov First Moscow State Medical University (Sechenov University), a Federal State Autonomous Educational Institution of Higher Education under the Ministry of Health of the Russian Federation. All study protocols and procedures were ethically reviewed and approved in accordance with institutional guidelines (approval no. 82839/2024). The need

for consent to participate was waived due to the retrospective nature of this study.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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