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Anatomical variations of the medial calcaneal nerve: a cadaveric study

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Abstract

Introduction One of the underestimated causes of pain in the heel area is neuropathy of the medial calcaneal nerve, which can both imitate and accompany plantar fasciitis. Some researchers note that neuropathy of the medial calcaneal branch of the tibial nerve is the cause of pain syndrome localized in the heel area. Knowledge of the main landmarks and anatomical variability of the medial calcaneal nerve passage in the foot can facilitate anesthesia, surgical interventions, including hydrodissection.

Purpose To determine the anatomical variability of the medial calcaneal nerve, including the level of its origin, transverse diameter and topographic location relative to the main anatomical landmarks of the medial calcaneal area in order to use the obtained data in foot surgery, regional anesthesia and differential diagnosis of pain syndrome localized in the calcaneal area.

Materials and methods Dissection of the medial heel region was performed in 16 cadavers (32 feet). For each specimen, we measured the thickness of the tibial and medial calcaneal nerves, as well as the distance (centimeters) from the tip of the medial malleolus to the point where the medial calcaneal nerve branched off from the tibial nerve, and to the bifurcation point of the tibial nerve into the medial and lateral plantar nerves.

Results The study found that the medial calcaneal nerve branched from the tibial nerve at a distance of 2.7 ± 0.7 cm distal to the tip of the medial malleolus. The cross-sectional diameter of the nerve varied and averaged 1.9 ± 1.2 cm. In 15.6 % of cases, the medial calcaneal nerve had an additional branch. In the vast majority of cases (72 %), it terminated within the subcutaneous fat of the medial aspect of the calcaneous.

Discussion The findings confirmed considerable anatomical variability of the medial calcaneal nerve. In 15.6 % of cases, it originated from the lateral plantar branch, which is consistent with the findings of other researchers. The morphological features of branching in the tibial nerve and its distal segments are of particular importance in foot surgery. Unintentional nerve injury is possible during interventions in the region of the tarsal tunnel (including radiofrequency denervation or endoscopic release).

Conclusion This cadaveric study confirmed marked anatomical variability of the medial calcaneal nerve. These findings expand our understanding of the variable anatomy of the heel area and may aid in interpreting clinical cases of pain caused by compression or trauma to the medial calcaneal nerve, as well as in performing regional anesthesia.

Keywords: medial calcaneal nerve, plantar fasciitis, anatomy of the medial calcaneous

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INTRODUCTION

Understanding the anatomy of the medial heel area of the foot is fundamental for the diagnosis and treatment of various diseases associated with pain in the foot. Plantar fasciitis is one of the most common diseases characterized by pain in the heel area. Pain in the heel area in patients with plantar fasciitis is often considered a manifestation of enthesopathy, but the cause of pain may also be associated with neuropathic factors [1]. Pathological changes in this disease occur primarily at the site of attachment of the plantar fascia to the calcaneus [2]. Pain persists throughout the period of professional activity, which has a significant negative impact on the quality of patients' life. The issue of chronic damage to the plantar fascia continues to be the subject of scientific discussions in contemporary traumatology and orthopaedics [3]. Researchers associate the development of plantar fasciitis with a number of predisposing factors, including biomechanical disorders, excessive mechanical loads, pronounced pronation of the foot, restriction of dorsiflexion in the ankle joint, as well as traumatic effects [4, 5].

One of the underestimated causes of pain in the heel area is neuropathy of the medial calcaneal nerve, which can both imitate and accompany plantar fasciitis. Some researchers note that neuropathy of the medial calcaneal branch of the tibial nerve is the cause of pain syndrome localized in the heel area [6, 7], which is also confirmed by electrophysiological studies [8]. Currently, this neuropathy is characterized as an independent nosological condition or as a concomitant condition in plantar fasciitis [9], since the transmission of afferent pain impulses occurs along the medial calcaneal nerve of the foot [10].

Purpose To determine the anatomical variability of the medial calcaneal nerve, including its origin level, transverse diameter and topographic location relative to the main anatomical landmarks of the medial calcaneal region in order to use the obtained data in foot surgery, regional anesthesia and differential diagnosis of pain syndrome localized in the calcaneal area.

MATERIAL AND METHODS

Dissection of the medial calcaneal region was performed in 32 feet of 16 cadavers (9 women and 7 men). The average age of women was (47 ± 11) years, their height averaged (164 ± 6) cm; the average age of men was (53 ± 12) years and their height was (175 ± 7) cm. Exclusion criteria for the use of cadaveric samples were visible signs of previous trauma or surgery in the ankle or foot area, pathological deformities, various injuries or external defects.

The study was conducted on the cadaveric material supplied for educational and scientific activities, in compliance with the current legislation of the Russian Federation regulating the handling of biological objects. All procedures complied with generally accepted ethical principles and did not contradict the Helsinki Declaration of the World Medical Association (2013 edition). The study was conducted at the facilities of the St. Petersburg State Healthcare Institution City Pathological Anatomy Bureau of the Kalininsky District (St. Petersburg).

Statistical processing was performed using Microsoft Excel and SPSS Statistics v.22. For quantitative variables, mean values, standard deviations (M±SD), and median (Me) were calculated. The normality of distribution was assessed using the Shapiro–Wilk test. For comparing two groups, Student's t-test or Mann–Whitney U-test were used depending on the type of distribution. Differences were considered statistically significant at $p < 0.05$.

Each lower limb was moved to the anatomical position and the foot was perpendicular to the tibial axis to minimize measurement errors. Skin and subcutaneous fat were dissected by forming a Y-shaped incision and the flaps were retracted for better visualization. The medial foot

tendon-muscle complex and plantar aponeurosis were partially removed to expose the nerve fibers. The tibial nerve and its branches were dissected from the distal third of the lower leg to the plantar surface. In this study, the thickness of the tibial nerve and medial calcaneal nerve, the distance (cm) from the apex of the medial malleolus to the point of origin of the medial calcaneal nerve from the tibial nerve, and the point of division of the tibial nerve into the medial and lateral plantar nerves were measured in each specimen. Additionally, the number of trunks of the medial calcaneal nerve (the number of separate branches extending from the tibial nerve to the calcaneal region) and the anatomical zone of the medial calcaneal nerve ending (in the subcutaneous fat of the calcaneal region or at the medial tuberosity of the calcaneus) were determined.

RESULTS

During dissection, the medial calcaneal nerve was found in all 32 feet. The diameter (thickness) of the tibial nerve in the tarsal canal region was (5.6 ± 0.5) mm (4.3–5.9 mm). The thickness (external diameter) of the medial calcaneal nerve varied from 0.5 to 5.4 mm, averaging (1.9 ± 1.2) mm (Fig. 1).

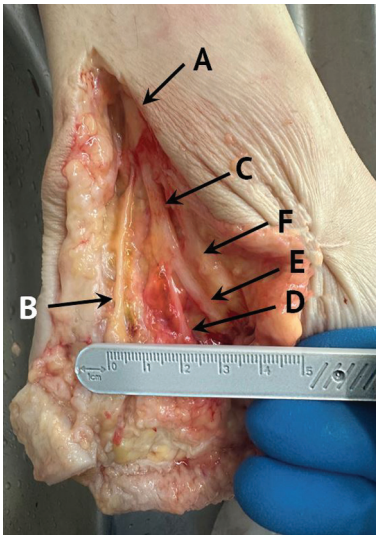

Fig. 1 Topographical picture of the medial calcaneal region: A — tibial nerve; B — medial calcaneal nerve; C — lateral plantar nerve; D — the first branch of the lateral plantar nerve; E — continuation of the lateral plantar nerve; F — medial plantar nerve

In most specimen (68.8 %, 22 cases), the thickness of the medial calcaneal nerve was 0.5–2.0 mm, in five cases (15.6 %) it was 2.1–3.0 mm, in two cases (6.3 %) it was 3.1–4.9 mm, and in three cases (9.4 %) it was greater than or equal to 5.0 mm (the maximum value was 5.4 mm) (Fig. 2).

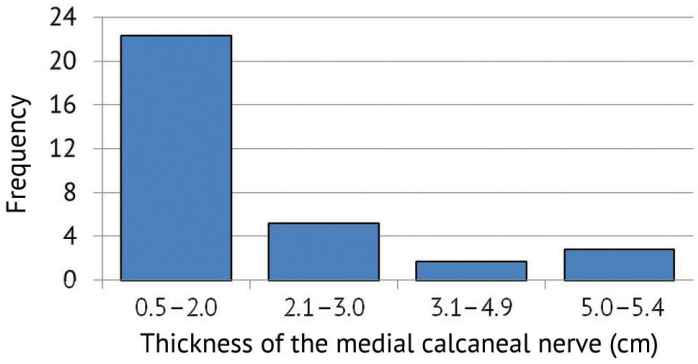

Fig. 2 Diagram of the distribution of the thickness of the medial calcaneal nerve

The medial calcaneal nerve originated from the tibial nerve at different levels relative to the apex of the medial malleolus: the minimum distance was 1.0 cm (proximal to the apex), the maximum was 4.5 cm (distal, towards the foot). The average level of origin of the medial calcaneal nerve was (2.7 ± 0.7) cm distal to the apex of the medial malleolus (Fig. 3).

In the absolute majority of specimen (84.4 %), the medial calcaneal nerve branched off from the tibial nerve as a single trunk. In five cases (15.6 %), two separate trunks of the medial calcaneal nerve were identified, branching off from the tibial nerve and directed to the medial tuberosity of the calcaneus and into the subcutaneous fat layer (Fig. 4).

Comparison of right and left feet revealed no significant differences in the morphometric parameters of the medial calcaneal nerve. There were also no differences in the thickness or origin of the medial calcaneal nerve depending on gender ($p = 0.541$) (Table 1).

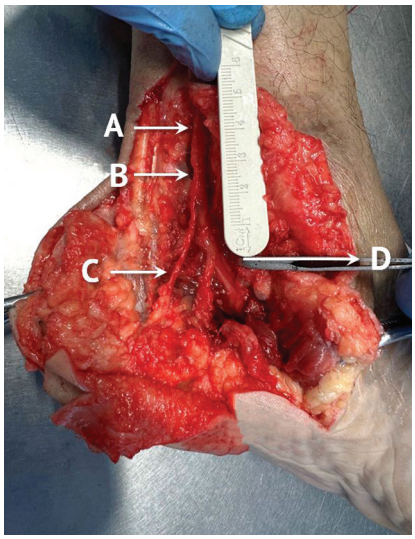

Fig. 3 Topographical picture of the medial calcaneal region: A — tibial nerve; B — level of the medial calcaneal nerve origination from the tibial nerve; C — medial calcaneal nerve; D — level of the apex of the medial malleolus

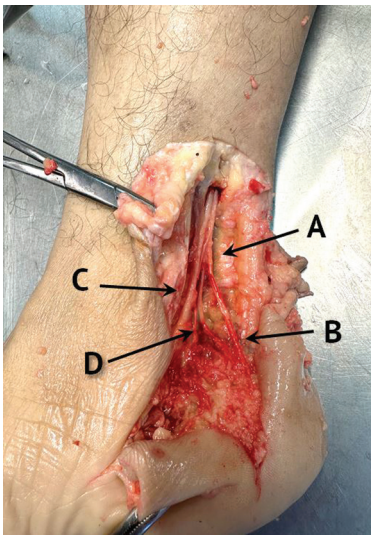

Fig. 4 Topographical picture of the medial calcaneal region: A — origin of the additional nerve trunk of the medial calcaneal nerve; B — medial calcaneal nerve; C — lateral plantar nerve; D — additional nerve trunk of the medial calcaneal nerve

Table 1

Medial calcaneal nerve thickness in the study group

Gender	*n*	Average thickness of the medial calcaneal nerve, mm	Standard deviation	Minimal value	Maximum value
Males	18	1.9	1.4	0.5	5.4
Females	14	2.1	1.2	0.7	5

In typical cases (more than 80 %), the medial calcaneal nerve branched off from the tibial nerve proximal to the bifurcation point for the medial and lateral plantar nerves. However, in five cases (15.6 %), an atypical picture was found: the medial calcaneal nerve branched off distal to the bifurcation. Thus, it branched off not directly from the trunk of the tibial nerve but from the lateral plantar nerve. Therefore, the medial calcaneal nerve was a branch of the lateral plantar nerve, indicating a developmental variant that is significant for understanding the variability of innervation of the calcaneal region. The termination point of the medial calcaneal nerve turned out to be relatively constant: 23 nerves (72 %) terminated in the subcutaneous fat of the calcaneal region, forming there a branched network of thin branches that provide sensitive innervation of the skin of the calcaneal region of the foot. In the remaining nine cases (28 %), the branch of the medial calcaneal nerve reached the region of the medial tuberosity of the calcaneus, where its terminal branches ran deep into the periosteum and ligamentous structures.

DISCUSSION

The medial calcaneal nerve is a small but clinically significant sensory branch that innervates the medial and posteromedial surfaces of the heel of the foot, including the area above the calcaneal tuberosity, the flexor retinaculum, and the subcutaneous fat of the calcaneal region [11]. The clinical picture of medial calcaneal nerve neuropathy includes burning pain, paresthesia, numbness, and hyperesthesia in the heel area. The pain increases with weight-bearing and in some cases occurs at night. Patients often describe the sensation as “electric shocks” or “burning” [12]. The relationship between plantar fasciitis and medial calcaneal nerve neuropathy has been confirmed by a number of clinical studies. According to a number of authors, up to 18 % of patients with chronic plantar fasciitis have signs of neuropathy. Verification of the diagnosis is especially important, since treatment methods for these conditions may differ [13].

Imaging techniques such as high-resolution ultrasonography and MRI can detect various morphological changes in tissues, including fibrosis, fascial thickening, and nerve compression [14]. Combining imaging data with electrophysiological studies helps differentiate neuropathic pain from enthesopathy and clarify the cause of chronic heel pain.

Chronic pain in the heel area can cause gait disturbance, compensatory overload of adjacent joints, and, as a consequence, secondary pathologies in other parts of the musculoskeletal system [15]. Early diagnosis and a multidisciplinary approach based on knowledge of anatomical features are key components of effective treatment of patients with pain in the heel area. Understanding the anatomy, topography, and branching patterns of the medial calcaneal nerve of the foot is essential in diagnosing heel pain, planning surgical interventions, and administering anesthesia.

According to anatomical studies, the sciatic nerve in the distal direction divides into its main trunks at the level of the popliteal fossa: the peroneal and tibial nerves. The tibial nerve passes behind the medial malleolus and enters the proximal part of the tarsal canal where it divides into the lateral plantar nerve, medial plantar nerve and medial calcaneal nerve. The branching of the main nerve trunks has anatomical variability, including the medial calcaneal nerve [16].

There is evidence in the literature that the medial calcaneal nerve arises from the tibial nerve within or proximal to the tarsal canal in most cases [17, 18]. The location of the medial calcaneal nerve is of great importance for the diagnosis and treatment of pain in the heel area, tarsal canal syndrome, soft tissue and joint injuries, and pain caused by perineurium fibrosis [19]. According to the literature, when the medial calcaneal nerve branches off from the main trunk, the tibial nerve, it is most often located superficially to the muscle that abducts the big toe and passes through or above the flexor retinaculum. The medial calcaneal nerve and its branches do not penetrate the plantar arch or deep structures of the foot [20]. The results obtained in the course of the study describe the origination of the medial calcaneal nerve from the tibial nerve (in more than 80 % of cases), which is consistent with the literature data.

The division of the medial calcaneal nerve into two main branches has been described: the anterior branch which goes to the muscle that abducts the big toe, and the posterior branch which runs to the skin, the medial surface of the Achilles tendon, the calcaneus, and the plantar fat pad [21]. Another study noted that the medial calcaneal nerve may branch off from the tibial nerve and/or the lateral plantar nerve [22]. Our data confirm this statement: the medial calcaneal nerve may branch off not directly from the tibial nerve but from the lateral plantar nerve. Similar variants have been mentioned previously, but according to our data, their frequency is about 15 %. This is somewhat lower than reported in some foreign studies (about 27 %), which may be due to the sample size [23].

Researchers have found that the medial calcaneal nerve can also arise from the medial plantar nerve, cross blood vessels in the calcaneal canal, and innervate the calcaneal region [24]. The number of medial calcaneal nerves may vary from one to four, but five also were described [25, 26]. In the present study, two separate trunks of the medial calcaneal nerve were found in five cases (15.6 %), arising from the tibial nerve and running to the medial tuberosity of the calcaneus and into the subcutaneous fat layer. More than two trunks were not found, which may be due to the sample size or individual characteristics of the biological samples studied.

The present study complements the existing anatomical data on the medial calcaneal nerve and highlights the need for an individualized approach to interventions in the heel area. The results may serve as a morphological basis for improving the diagnosis and prevention of neuropathic heel pain.

The results demonstrate significant anatomical variability of the medial calcaneal nerve. In particular, the level of origination of the medial calcaneal nerve from the tibial nerve varies in the range from 1 cm distal to 4.5 cm proximal relative to the landmark (apex of the medial malleolus). This confirms the data of several studies on the variability of the routes of the calcaneal branches of the tibial nerve. The study presents data on the thickness (diameter) of the medial calcaneal nerve on cadaveric material, quantitatively describing this parameter with the calculation of average and extreme values.

CONCLUSION

The anatomy of the tarsal canal and calcaneal nerves is important for orthopedists, traumatologists, and neurosurgeons who perform foot surgery. Moreover, the variability in the thickness of the medial calcaneal nerve means that the severity of clinical manifestations in its neuropathy may vary as larger trunks are potentially more vulnerable to compression. For neurologists, knowledge of the variants of the medial calcaneal nerve termination is important in diagnosing lesions. Thus, in subcutaneous position of the medial calcaneal nerve end, a superficial location of pain points is possible, while if it terminates at the calcaneus, symptoms can imitate plantar fasciitis. Knowledge of the main landmarks and anatomical variability of the passage of additional trunks of the medial calcaneal nerve can facilitate anesthesia, surgical interventions, including hydrodissection.

Conflict of interests *The authors declare no obvious or potential conflicts of interest related to the publication of this study.*

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Ethical standards *The study was conducted in accordance with the ethical standards of the World Medical Association Declaration of Helsinki.*

REFERENCES

1. Allam AE, Chang KV. Plantar heel pain. 2024. In: *StatPearls [Internet]*. Treasure Island (FL): StatPearls Publishing; 2025.
2. Airapetov GA, Agafonov DG, Serdobintsev MS, Kaftyrev AS. Views about the clinical, diagnostic and comprehensive treatment of plantar fasciitis: a review. *Bulletin of Rehabilitation Medicine*. 2024;23(2):49-56. (In Russ.) doi: 10.38025/2078-1962-2024-23-2-49-56.
3. Sajja S, Elahi N, Ganti L. Plantar Fasciitis With a Calcaneal Spur. *Cureus*. 2023;15(12):e51242. doi: 10.7759/cureus.51242.
4. Luffy L, Grosel J, Thomas R, So E. Plantar fasciitis: A review of treatments. *JAAPA*. 2018;31(1):20-24. doi: 10.1097/01.JAA.0000527695.76041.99.
5. Li S, Wang K, Sun H, et al. Clinical effects of extracorporeal shock-wave therapy and ultrasound-guided local corticosteroid injections for plantar fasciitis in adults: A meta-analysis of randomized controlled trials. *Medicine (Baltimore)*. 2018;97(50):e13687. doi: 10.1097/MD.0000000000013687.
6. Fortier LM, Leethy KN, Smith M, et al. An Update on Posterior Tarsal Tunnel Syndrome. *Orthop Rev (Pavia)*. 2022;14(4):35444. doi: 10.52965/001c.35444.
7. Arslan A, Koca TT, Utkan A, et al. Treatment of Chronic Plantar Heel Pain With Radiofrequency Neural Ablation of the First Branch of the Lateral Plantar Nerve and Medial Calcaneal Nerve Branches. *J Foot Ankle Surg*. 2016;55(4):767-771. doi: 10.1053/j.jfas.2016.03.009.
8. Seo JH, Oh SJ. Near-nerve needle sensory conduction study of the medial calcaneal nerve: New method and report of four cases of medial calcaneal neuropathy. *Muscle Nerve*. 2002;26(5):654-658. doi: 10.1002/mus.10264.
9. Rodríguez-Merchán EC, Moracia-Ochagavía I. Tarsal tunnel syndrome: current rationale, indications and results. *EFORT Open Rev*. 2021;6(12):1140-1147. doi: 10.1302/2058-5241.6.210031.
10. Diers DJ. Medial calcaneal nerve entrapment as a cause for chronic heel pain. *Physiother Theory Pract*. 2008;24(4):291-298. doi: 10.1080/09593980701738392.
11. Priya A, Ghosh SK, Walocha JA, et al. Variations in the branching pattern of tibial nerve in foot: a review of literature and relevant clinical anatomy. *Folia Morphol (Warsz)*. 2023;82(2):231-241. doi: 10.5603/FM.a2022.0042.
12. Cheong IY, Kim KH, Park BK, Kim DH. Medial calcaneal neuropathy as a cause of intractable heel pain. *Am J Phys Med Rehabil*. 2016;95(4):e62. doi: 10.1097/PHM.0000000000000444.
13. Potocnik P, Hochreiter B, Harrasser N, et al. Differential diagnosis of heel pain. *Orthopade*. 2019;48(3):261-280. (In German) doi: 10.1007/s00132-019-03690-0.
14. Bordalo M, Felippe de Paula Correa M, Yamashiro E. High-resolution ultrasound of the foot and ankle. *Clin Podiatr Med Surg*. 2024;41(4):853-864. doi: 10.1016/j.cpm.2024.04.013.
15. Herchenröder M, Wilfling D, Steinhäuser J. Evidence for foot orthoses for adults with flatfoot: a systematic review. *J Foot Ankle Res*. 2021;14(1):57. doi: 10.1186/s13047-021-00499-z.
16. Warchol Ł, Walocha JA, Mizia E, et al. Ultrasound-guided topographic anatomy of the medial calcaneal branches of the tibial nerve. *Folia Morphol (Warsz)*. 2021;80(2):267-274. doi: 10.5603/FM.a2020.0062.
17. Awadelseid KMF. Branching pattern of the medial calcaneal neurovascular bundle in porta pedis of the human foot. *Int J Hum Anatom*. 2019;1(4):2-12. doi: 10.14302/issn.2577-2279.ijha-19-3013.

18. Lopes JG, Rodrigues-Pinho A, Neves MA, et al. An anatomical approach to the tarsal tunnel syndrome: what can ankle's medial side anatomy reveal to us? *J Foot Ankle Res*. 2023;16(1):80. doi: 10.1186/s13047-023-00682-4.
19. Moroni S, Zwierzina M, Starke V, et al. Clinical-anatomic mapping of the tarsal tunnel with regard to Baxter's neuropathy in recalcitrant heel pain syndrome: part I. *Surg Radiol Anat*. 2019;41(1):29-41. doi: 10.1007/s00276-018-2124-z.
20. Louisia S, Masquelet AC. The medial and inferior calcaneal nerves: an anatomic study. *Surg Radiol Anat*. 1999;21(3):169-173. doi: 10.1007/BF01630895.
21. Govsa F, Bilge O, Ozer MA. Variations in the origin of the medial and inferior calcaneal nerves. *Arch Orthop Trauma Surg*. 2006;126(1):6-14. doi: 10.1007/s00402-005-0088-z.
22. Kwon J, Park HB, Kwon S, et al. Morphometric assessment of tibial nerve and its branches around the ankle. *Medicine (Baltimore)*. 2024;103(15):e37745. doi: 10.1097/MD.0000000000037745.
23. Kim BS, Choung PW, Kwon SW, et al. Branching patterns of medial and inferior calcaneal nerves around the tarsal tunnel. *Ann Rehabil Med*. 2015;39(1):52-55. doi: 10.5535/arm.2015.39.1.52.
24. Dellon AL, Kim J, Spaulding CM. Variations in the origin of the medial calcaneal nerve. *J Am Podiatr Med Assoc*. 2002;92(2):97-101. doi: 10.7547/87507315-92-2-97.
25. Kim DI, Kim YS, Han SH. Topography of human ankle joint: focused on posterior tibial artery and tibial nerve. *Anat Cell Biol*. 2015;48(2):130-137. doi: 10.5115/acb.2015.48.2.130.
26. Dellon AL, Mackinnon SE. Tibial nerve branching in the tarsal tunnel. *Arch Neurol*. 1984;41(6):645-646. doi: 10.1001/archneur.1984.04210080053013.

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Airapetov G.A. — conceptualization, methodology, research, supervision, project management.

Serdobintsev M.S. — reviewing and editing.

Karpovich N.I. — data collection, analysis or interpretation.

Khanmuradov R.A. — validation, data processing.

Naumov D.G. — approval of the final manuscript for publication

Djeriev M. A. — formal analysis.