УДК 616.211-089:616.213.1:544.032.65
DOI: https://doi.org/10.33848/fopr627056

Выбор параметров воздействия тулиевого волоконного лазера (длина волны — 1,94 мкм) для подслизистой коагуляции нижних носовых раковин

С.А. Карпищенко, М.А. Рябова, М.Ю. Улупов, Г.Ю. Юкина, Е.Г. Сухорукова, Ж.О. Рахмонов

Первый Санкт-Петербургский государственный медицинский университет имени академика И.П. Павлова, Санкт-Петербург, Россия

АННОТАЦИЯ

Обоснование. Медикаментозное лечение вазомоторного ринита часто оказывается малоэффективным. Хирургические методы лечения вазомоторного ринита могут быть сравнительно эффективными, однако они нередко сопряжены с риском кровотечения и могут потребовать тампонады полости носа и последующего стационарного лечения. Для выбора параметров лазерного воздействия длиной волны 1,94 мкм на носовые раковины при лечении вазомоторного ринита исследованы коагуляционные возможности интерстициального воздействия этим лазером на ткани телячьей почки с оценкой морфологических изменений.

Цель — определить оптимальный режим интерстициального воздействия лазером с длиной волны 1,94 мкм на ткань телячьей почки для достижения максимальной коагуляции.

Материалы и методы. Задача исследования — выполнить интерстициальную коагуляцию на ткани телячьей почки на мощностях от 1 до 5 Вт с интервалом 1 Вт. Скорость движения волокна составляла 4 мм/с. Для статистического анализа воздействие с каждым уровнем мощности было повторено пять раз, получено по десять образцов материалов для гистологического исследования и морфометрии.

Результаты. При интерстициальном воздействии наибольший размер области коагуляции отмечается при мощности 3 Вт, общий диаметр воздействия составляет в среднем 2,57 ± 0,1 мм.

Ключевые слова: вазомоторный ринит; интерстициальное лазерное воздействие; лазер с длиной волны излучения 1,94 мкм.

Как цитировать

Карпищенко С.А., Рябова М.А., Улупов М.Ю., Юкина Г.Ю., Сухорукова Е.Г., Рахмонов Ж.О. Выбор параметров воздействия тулиевого волоконного лазера (длина волны — 1,94 мкм) для подслизистой коагуляции нижних носовых раковин // Folia Otorhinolaryngologiae et Pathologiae Respiratoriae. 2024. Т. 30. № 1. С. 27–33. DOI: https://doi.org/10.33848/fopr627056

Рукопись получена: 17.02.2024 **Рукопись одобрена:** 17.06.2024 **Опубликована online:** 21.06.2024

DOI: https://doi.org/10.33848/fopr627056

Selection of 1.94-μm thulium fiber laser parameters for the submucosal coagulation of the inferior turbinates

Sergey A. Karpishchenko, Marina A. Ryabova, Mikhail Yu. Ulupov, Galina Yu. Yukina, Elena G. Sukhorukova, Jakhongir O. Rakhmonov

Academician I.P. Pavlov First Saint Petersburg State Medical University, Saint Petersburg, Russia;

ABSTRACT

BACKGROUND: Medical treatment often provides only short-term relief and is ineffective in many cases. Although surgical interventions for vasomotor rhinitis are effective, they are also associated with significant bleeding, nasal tamponade, and hospitalization.

AIM: This study aimed to determine the optimal parameters for laser treatment using a 1.94-μm wavelength on nasal turbinates in vasomotor rhinitis.

MATERIALS AND METHODS: The coagulation potential of the 1.94-μm wavelength on calf kidney tissue was investigated to guide the selection of laser parameters for nasal turbinates. Interstitial coagulation was performed on calf kidney tissue at power levels ranging from 1 to 5 W, with an interval of 1 W. The fiber movement speed was set at 4 mm/s. Each power level was tested five times for statistical analysis, and 10 samples were obtained for histological assessment.

RESULTS: With interstitial exposure, the largest coagulation area was observed at 3 W, and the overall diameter of the effect was on average 2.57 ± 0.1 mm.

CONCLUSIONS: The optimal balance between coagulation and ablation was achieved at a power level of 3 W during interstitial exposure.

Keywords: vasomotor rhinitis; interstitial laser exposure; nasal turbinates; 1.94-μm wavelength laser.

To cite this article

Karpishchenko SA, Ryabova MA, Ulupov MYu, Yukina GYu, Sukhorukova EG, Rakhmonov JO. Selection of 1.94-μm thulium fiber laser parameters for the submucosal coagulation of the inferior turbinates. *Folia Otorhinolaryngologiae et Pathologiae Respiratoriae.* 2024;30(1):27–33. DOI: https://doi.org/10.33848/fopr627056

Received: 17.02.2024 **Accepted:** 17.06.2024 **Published online:** 21.06.2024

BACKGROUND

Vasomotor rhinitis is a chronic disease that is characterized by nasal congestion and hypersecretion. Furthermore, its development is influenced by both external and internal factors. However, it is not an immunologic reaction, and it is not associated with eosinophilia [1].

Medical treatment often has a short-term effect and may even be ineffective [2]. There are several methods of surgical treatment of vasomotor rhinitis, including interstitial disintegration of the nasal vessels with cold instruments, superficial coagulation of the nasal cavities with radiofrequency instruments [3], and cryodestruction with liquid nitrogen [12]. However, these methods can be harsh and may be accompanied by significant bleeding that may require nasal tamponade and hospitalization.

The demand for laser technologies in medicine is increasing. Laser treatments for vasomotor rhinitis have been in development for over 30 years, with extensive studies on the potential and limitations of the following wavelengths: 1.06 μm, 0.81 μm, and 0.97 μm [4]. Currently, the interstitial and superficial effects of laser on the nasal cavities are being used for the surgical treatment of vasomotor rhinitis. For this purpose, water-absorbed lasers with a wavelength of 1.94 μm have demonstrated promising results. The lasers demonstrate a balanced between their coagulation and ablation properties, and they provide reliable hemostasis [5–7].

The 1.94-μm thulium laser is reportedly safe and suitable for the treatment of endobronchial lesions, dermatoses, and benign prostatic obstruction. There are also anecdotal reports of the treatment of nasal mucosa hyperplasia with superficial laser therapy (average power, 3 W) [8–10]. However, there is no evidence of its long-term effects and no clear understanding of its direct exposure and interstitial exposure capabilities.

In an experimental study on chicken muscle tissue, the cutting and coagulation properties of fiber lasers with wavelengths of 1.56 μm and 1.94 μm were compared with the cutting and coagulation properties of a 0.98-μm semiconductor laser. The study findings revealed some differences in the biological effects of the tested water-absorbing lasers [11]. The corresponding morphological changes were studied to determine the parameters of the 1.94-μm laser to be applied to the nasal shells in the treatment of vasomotor rhinitis.

In this study, we aimed to determine the optimal mode of interstitial exposure of the calf kidney tissue with a 1.94-μm laser to achieve maximum coagulation.

MATERIAL AND METHODS

Four calf kidneys were used as target tissue in this study. After the animal was euthanized, the kidneys were harvested, cooled to 4°C and used within 24 h.

On each kidney, 30-mm incisions were made parallel to each other using a laser. A gap of 8–10 mm was maintained between the incisions to eliminate the influence of one incision on another.

The emission wavelength of the thulium fiber laser used was 1.94 μm, and the maximum power was 10 W. A light guide with a direct output of 600 μm/3-m radiation was used.

Interstitial tissue effects were generated at a speed of 4 mm/s and a length of 30 mm. The laser was applied for 15 s, from the entry into the tissue up to 30 mm distally (in 7.5 s) and back. The exposure power was increased from 1 W to 5 W at the rate of 1 W (Figure 1).

Ten specimens were obtained for each type of study. The specimens were stained with Mayer's hematoxylin and eosin (Biovitrum, Russia), and they were analyzed under a light microscope (Eclipse Ni; Nikon, Japan) using the 10× eyepiece and the 4×, 10×, and 20× objectives. Digital images were obtained using a DS-Ri2 camera (Nikon, Japan) at 40× magnification. Morphometric analysis was performed using Nis Elements Basic Research (version X; Nikon, Japan). The depth of laser exposure was estimated as a function of laser power. Dependency diagrams of the coagulation depth on the laser exposure power were prepared using histological measurements (Figures 2–5, Tables 1–3).

RESULTS

At, The coagulation zone was significantly larger at 2 W (0.66 mm) and 3 W (0.77 mm) than at the other power levels.

The coagulation zone was the least at 4 W and 5 W. This may have occurred because the ablation zone was larger at 4 W (2.6 mm) and 5 W (2.8 mm) than at the other levels. A larger ablation zone indicates that most of the radiation energy went into the ablation process.

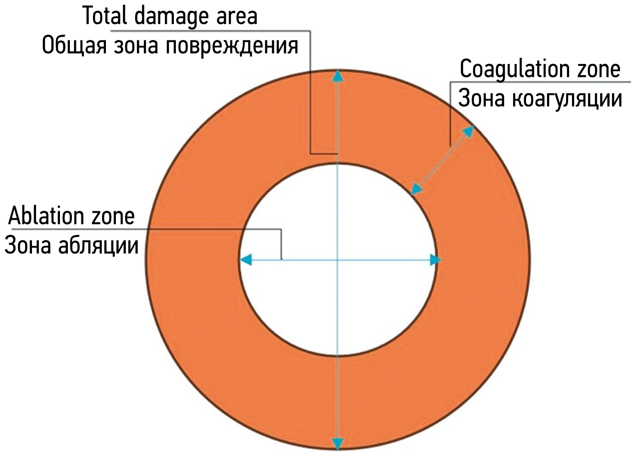

Fig. 1. Schematic of the damage
Рис. 1. Схема зоны повреждения

DOI: https://doi.org/10.33848/fopr627056

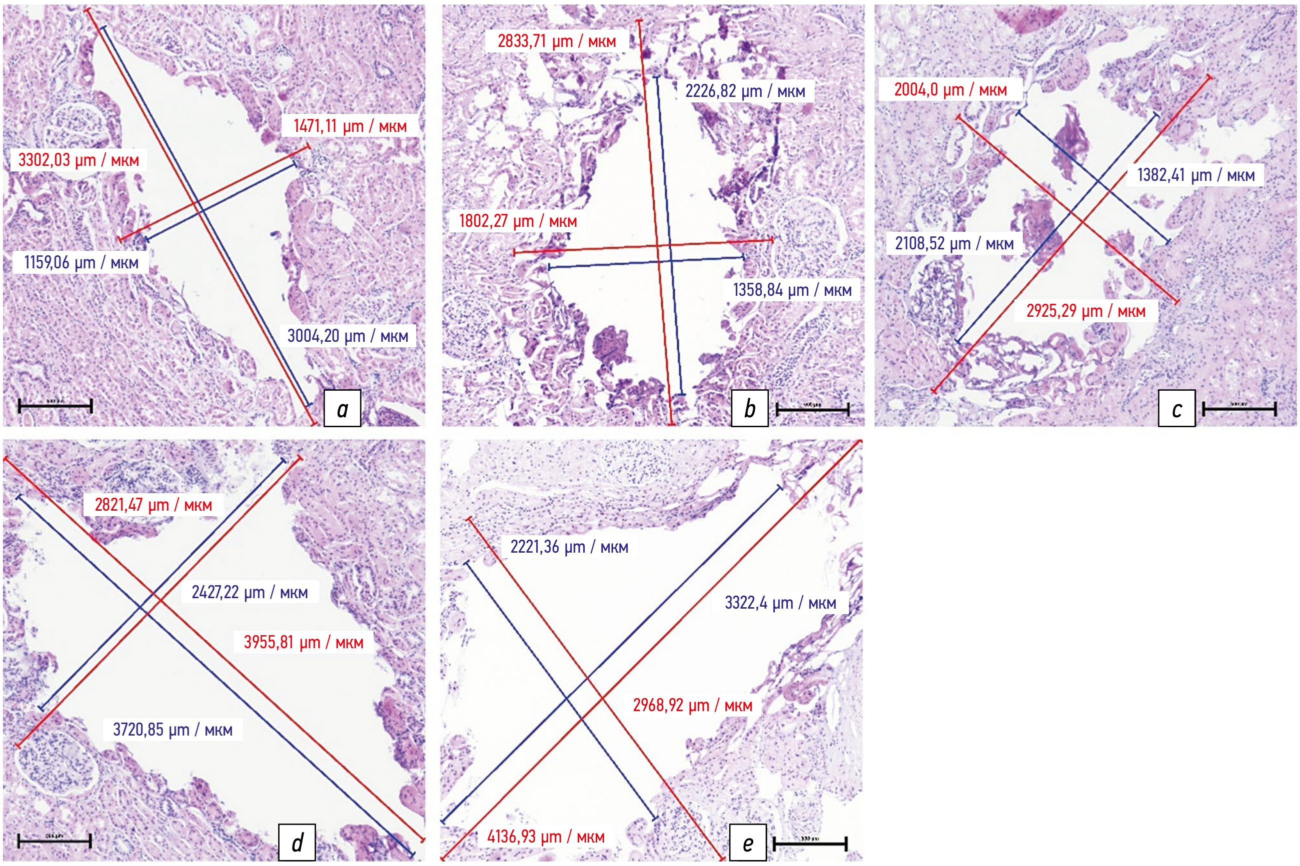

Fig. 2. Microscopic picture of pathologic changes in the biological tissue (calf kidney) after laser interstitial exposure to 1.94-μm wavelength laser: (*a*) 1 W, (*b*) 2 W, (*c*) 3 W, (*d*) 4 W, and (*e*) 5 W. Blue line, ablation zone; red line, ablation and coagulation zones

Рис. 2. Микроскопическая картина биологической ткани (телячий почки) после интерстициального воздействия лазером длиной волны 1,94 мкм: *a* — на мощности 1 Вт; *b* — на мощности 2 Вт; *c* — на мощности 3 Вт; *d* — на мощности 4 Вт; *e* — на мощности 5 Вт. Синяя линия — зона абляции, красная линия — зоны абляции и коагуляции

We found that 4 mm/s is the optimal speed for interstitial laser treatment. Higher speeds produced shallow coagulation depths, which may have not produced sufficient scarring and long-term reduction of the cavernous tissue volume. A lower speed may produce more thermal damage to the tissue than a higher speed, resulting in a larger ablation zone. Thus, a smaller coagulation zone may be associated with an increased risk of intra- and post-operative bleeding.

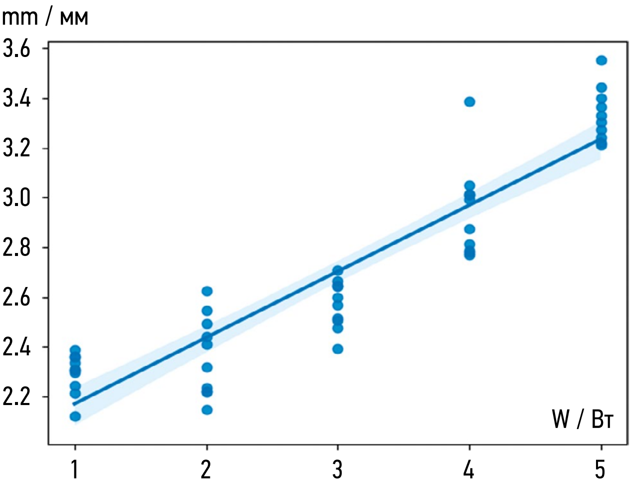

Fig. 3. Diameter of total tissue damage as a function of power

Рис. 3. Диаметр общего повреждения ткани в зависимости от мощности

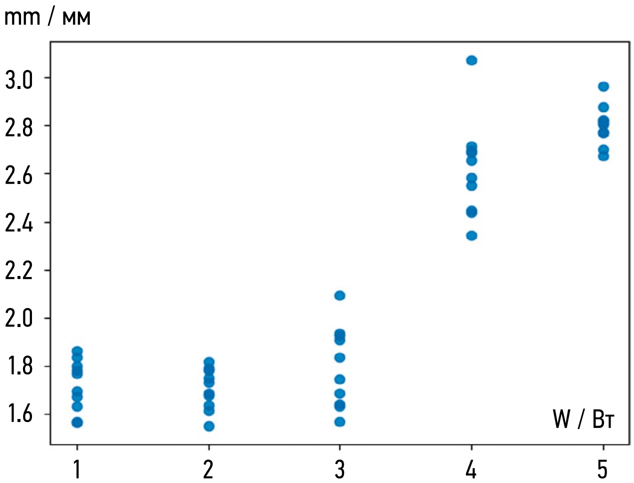

Fig. 4. Ablation zone diameter depending on power

Рис. 4. Диаметр зоны абляции в зависимости от мощности

DOI: https://doi.org/10.33848/fopr627056

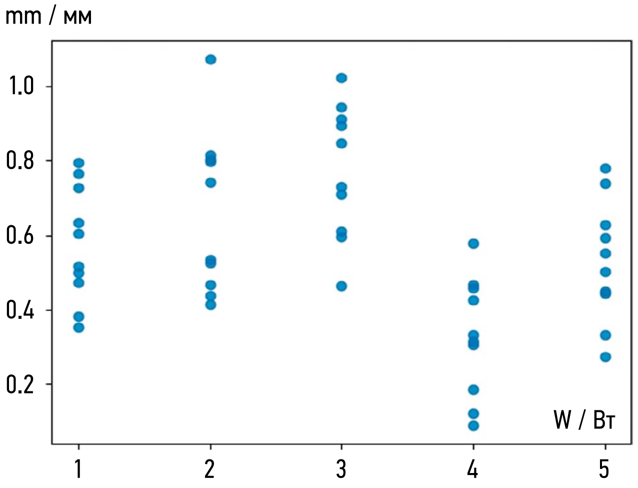

Fig. 5. Coagulation thickness as a function of power

Рис. 5. Толщина коагуляции в зависимости от мощности

CONCLUSIONS

To produce interstitial coagulation of the lower nasal shells in vasomotor rhinitis, the 1.94-µm laser should be applied at 3 W. This is based on the finding that at a fiber conduction velocity of 4 mm/s and reciprocating fiber movement in the tissues, the coagulation zone produced is larger at 3 W than at other powers, while the ablation zone is small.

Table 1. Total diameter of the lesion

Таблица 1. Общий диаметр повреждения

Indicator	1 W	2 W	3 W	4 W	5 W
Mean, mm	2.29	2.37	2.57	2.95	3.33
Standard deviation, mm	0.08	0.16	0.10	0.19	0.11
Minimum, mm	2.12	2.15	2.39	2.77	3.21
Maximum, mm	2.39	2.62	2.71	3.39	3.55

Table 2. Ablation diameter of the laser

Таблица 2. Диаметр абляции

Indicator	1 W	2 W	3 W	4 W	5 W
Mean, mm	1.72	1.70	1.80	2.62	2.80
Standard deviation, mm	0.11	0.09	0.17	0.20	0.08
Minimum, mm	1.56	1.55	1.57	2.35	2.68
Maximum, mm	1.86	1.82	2.10	3.07	2.97

Table 3. Coagulation thickness of the laser

Таблица 3. Толщина коагуляции

Indicator	1 W	2 W	3 W	4 W	5 W
Mean, mm	0.58	0.66	0.77	0.33	0.53
Standard deviation, mm	0.16	0.22	0.18	0.16	0.16
Minimum, mm	0.35	0.42	0.47	0.09	0.27
Maximum, mm	0.79	1.07	1.02	0.58	0.78

ADDITIONAL INFORMATION

Author contribution. All the authors have made a significant contribution to the development of the concept, research, and preparation of the article as well as read and approved the final version before its publication.

Personal contribution of the authors: *S.A. Karpishchenko* — checking critical content, editing, making final edits, approving the publication of the manuscript; *M.A. Ryabova* — collection and processing of material, conceptualization of the study, making final edits; *M.Yu. Ulupov* — analysis of data obtained, literature review, making final edits; *G.Yu. Yukina* — statistical processing of materials, preparation of illustration; *E.G. Sukhorukova* — statistical processing of materials, preparation of illustration; *J.O. Rakhmonov* — collection and processing of material, statistical processing of material, analyzing the obtained data, concept and design of the study, writing the text.

Funding source. There was no funding for the research.

Competing interests. The authors declare that they have no competing interests.

Ethics approval. Conclusion of the St. Petersburg State Pediatric Medical University commission on the possibility of open publication dated March 13, 2024.

Consent for publication. Written consent was obtained from the patients for publication of relevant medical information and all accompanying images within the manuscript.

Acknowledgments. The authors express their gratitude to the staff of the otorhinolaryngology department of Academician I.P. Pavlov First Saint Petersburg State Medical University for provided materials.

ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. Все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией.

Наибольший вклад распределен следующим образом: *С.А. Карпищенко* — проверка критически важного содержания, редактирования, внесение окончательной правки, утверждение рукописи для публикации; *М.А. Рябова* — сбор и обработка материала, концепция исследования, внесение окончательной правки; *М.Ю. Улупов* — анализ полученных данных, обзор литературы, внесение окончательной правки; *Г.Ю. Юкина* — статистическая обработка материалов, подготовка иллюстрации; *Е.Г. Сухорукова* — статистическая обработка материалов, подготовка иллюстраций; *Ж.О. Рахмонов* — сбор и обработка материала, статистическая обработка материалов, анализ полученных данных, концепция и дизайн исследования, написание текста.

Источник финансирования. Финансирование исследования отсутствовало.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией статьи.

Этический комитет. Заключение комиссии СПбГПМУ о возможности открытого публикования от 13.03.2024.

Информированное согласие на публикацию. Авторы получили письменное согласие пациентов на публикацию медицинских данных и фотографий.

Благодарности. Авторы выражают благодарность сотрудникам клиники оториноларингологии Первого Санкт-Петербургского государственного медицинского университета им. акад. И.П. Павлова за предоставленные материалы.

REFERENCES

1. Aref'eva NA, Vishnyakov VV, Karpishchenko SA, et al. *Vasomotor rhinitis: pathogenesis, diagnosis and principles of treatment. Clinical recommendations*. Moscow, 2014. 25 p. (In Russ.) EDN: SBUFCA

2. Segboer C, Gevorgyan A, Avdeeva K, et al. Intranasal corticosteroids for non-allergic rhinitis. *Cochrane Database Syst Rev.* 2019;2019(11):CD010592. doi: 10.1002/14651858.CD010592.pub2

3. Abdullah B, Singh S. Surgical interventions for inferior turbinate hypertrophy: a comprehensive review of current techniques and technologies. *Int J Environ Res Public Health*. 2021;18(7):3441. doi: 10.3390/ijerph18073441

4. Karpishchenko SA, Ryabova MA, Ulupov MY. Laser surgery in otolaryngology at the present stage. *Consilium Medicum.* 2014;16(11):73–76. EDN: TESNBT

5. Karpishchenko SA, Riabova MA, Ulupov MYu, et al. The choice of parameters for the laser application in ENT surgery. *Russian Bulletin of Otorhinolaryngology*. 2016;81(4):14–18. EDN: WHZZXR doi: 10.17116/otorino201681414-18

6. Lau K, Stavrakas M, Ray J. Lasers in rhinology: an update. *Ear Nose Throat J.* 2021;100(1_suppl):77S–82S. doi: 10.1177/0145561320940115

7. Kang SH, Lim S, Oh D, et al. Clinical feasibility trial of 1,940-nm diode laser in Korean patients with inferior turbinate hypertrophy. *Medical Lasers.* 2015;4(2):60–64. doi: 10.25289/ML.2015.4.2.60

8. Ryabova MA, Ulupov MY, Shumilova NA, et al. Possibilities of sparing surgical treatment of vasomotor rhinitis in elderly. *Folia Otorhinolaryngologiae et Pathologiae Respiratoriae.* 2020;26(4):50–58. EDN: BLEEVM doi: 10.33848/foliorl23103825-2020-26-4-50-58

9. Sroka R, Havel M, Betz C, et al. Clinical feasibility trial on 1940 nm Tm: fiber laser intervention of hyperplastic inferior nasal turbinates. *Photonics Lasers Med.* 2012;1(3):215–222. doi: 10.1515/plm-2012-0021

10. Anderson M, Liang J. Trends in inferior turbinate surgery: analysis of patients using the Medicare database. *Int Forum Allergy Rhinol.* 2018;8(10):1169–1174. doi: 10.1002/alr.22169

11. Ryabova MA, Ulupov MYu, Shumilova NA, et al. Comparison of cutting and coagulation properties of 1.56 and 1.94 μm fiber lasers and 0.98 μm semiconductor laser. *Bulletin of Siberian Medicine.* 2021;20(4):56–62. EDN: TIMMAW doi: 10.20538/1682-0363-2021-4-56-62

12. Shakhnazarov AE, Lavrenova GV, Gaskova PI. Treatment of vasomotor rhinitis with liquid nitrogen. *Folia Otorhinolaryngologiae et Pathologiae Respiratoriae.* 2022;28(2):72–78. EDN: AOHCDY doi: 10.33848/foliorl23103825-2022-28-2-72-78

СПИСОК ЛИТЕРАТУРЫ

1. Арефьева Н.А., Вишняков В.В., Карпищенко С.А., и др. Вазомоторный ринит: патогенез, диагностика и принципы лечения. Клинические рекомендации: учебное пособие. Москва, 2014. 25 с. EDN: SBUFCA

2. Segboer C., Gevorgyan A., Avdeeva K., et al. Intranasal corticosteroids for non-allergic rhinitis // Cochrane Database Syst Rev. 2019. Vol. 2019, N 11. P. CD010592. doi: 10.1002/14651858.CD010592.pub2

3. Abdullah B., Singh S. Surgical interventions for inferior turbinate hypertrophy: a comprehensive review of current techniques and technologies // Int J Environ Res Public Health. 2021. Vol. 18, N 7. P. 3441. doi: 10.3390/ijerph18073441

4. Карпищенко С.А., Рябова М.А., Улупов М.Ю. Лазерная хирургия в оториноларингологии на современном этапе // Consilium Medicum. 2014. Т. 16, № 11. С. 73–76. EDN: TESNBT

5. Карпищенко С.А., Рябова М.А., Улупов М.Ю., и др. Выбор параметров лазерного воздействия в хирургии ЛОР-органов // Вестник оториноларингологии. 2016. Т. 81, № 4. С. 14–18. EDN: WHZZXR doi: 10.17116/otorino201681414-18

6. Lau K., Stavrakas M., Ray J. Lasers in rhinology – an update // Ear Nose Throat J. 2021. Vol. 100, N 1_Suppl. P. 77S–82S. doi: 10.1177/0145561320940115

7. Kang S.H., Lim S., Oh D., et al. Clinical feasibility trial of 1,940-nm diode laser in Korean patients with inferior turbinate hypertrophy // Medical Lasers. 2015. Vol. 4, N 2. P. 60–64. doi: 10.25289/ML.2015.4.2.60

8. Рябова М.А., Улупов М.Ю., Шумилова Н.А., и др. Возможности щадящего хирургического лечения вазомоторного ринита у пожилых // Folia Otorhinolaryngologiae et Pathologiae Respiratoriae. 2020. Т. 26, № 4. С. 50–58. EDN: BLEEVM doi: 10.33848/foliorl23103825-2020-26-4-50-58

9. Sroka R., Havel M., Betz C., et al. Clinical feasibility trial on 1940 nm Tm: fiber laser intervention of hyperplastic inferior nasal turbinates // Photonics Lasers Med. 2012. Vol. 1, N 3. P. 215–222. doi: 10.1515/plm-2012-0021

10. Anderson M., Liang J. Trends in inferior turbinate surgery: analysis of patients using the Medicare database // Int Forum Allergy Rhinol. 2018. Vol. 8, N 10. P. 1169–1174. doi: 10.1002/alr.22169

11. Рябова М.А., Улупов М.Ю., Шумилова Н.А., и др. Сравнение режущих и коагуляционных свойств волоконных лазеров с длиной волны 1,56 и 1,94 мкм с полупроводниковым лазером 0,98 мкм // Бюллетень сибирской медицины. 2021. Т. 20, № 4. С. 56–62. EDN: TIMMAW doi: 10.20538/1682-0363-2021-4-56-62

12. Шахназаров А.Э., Лавренова Г.В., Гаськова П.И. Лечение вазомоторного ринита с помощью жидкого азота // Folia Otorhinolaryngologiae et Pathologiae Respiratoriae. 2022. Т. 28, № 2. С. 72–78. EDN: AOHCDY doi: 10.33848/foliorl23103825-2022-28-2-72-78

AUTHORS INFO

Sergey A. Karpishchenko, MD, Dr. Sci. (Medicine), Professor;
ORCID: 0000-0003-1124-1937;
eLibrary SPIN: 1254-0263;
e-mail: karpischenkos@mail.ru

Marina A. Ryabova, MD, Dr. Sci. (Medicine), Professor;
ORCID: 0000-0002-6714-9454;
eLibrary SPIN: 3951-7190;
e-mail: marinaryabova@mail.ru

Mikhail Yu. Ulupov, MD, Cand. Sci. (Medicine), Assistant Professor;
ORCID: 0000-0002-8460-9889;
eLibrary SPIN: 1851-8202;
e-mail: mike.ulupov@gmail.com

Galina Yu. Yukina, Assistant Professor;
ORCID: 0000-0001-8888-4135;
eLibrary SPIN: 2533-2084;
e-mail: pipson@inbox.ru

Elena G. Sukhorukova;
ORCID: 0000-0001-5521-7248;
eLibrary SPIN: 2115-9041;
e-mail: len48@inbox.ru

*** Jakhongir O. Rakhmonov**, Postgraduate student;
address: 6-8 L'va Tolstogo St., Saint Petersburg, 197022, Russia;
ORCID: 0009-0005-9176-0156;
e-mail: janik.27@mail.ru

ОБ АВТОРАХ

Сергей Анатольевич Карпищенко, д-р мед. наук, профессор;
ORCID: 0000-0003-1124-1937;
eLibrary SPIN: 1254-0263;
e-mail: karpischenkos@mail.ru

Марина Андреевна Рябова, д-р мед. наук, профессор;
ORCID: 0000-0002-6714-9454;
eLibrary SPIN: 3951-7190;
e-mail: marinaryabova@mail.ru

Михаил Юрьевич Улупов, канд. мед. наук, доцент;
ORCID: 0000-0002-8460-9889;
eLibrary SPIN: 1851-8202;
e-mail: mike.ulupov@gmail.com

Галина Юрьева Юкина, доцент;
ORCID: 0000-0001-8888-4135;
eLibrary SPIN: 2533-2084;
e-mail: pipson@inbox.ru

Елена Геннадьевна Сухорукова;
ORCID: 0000-0001-5521-7248;
eLibrary SPIN: 2115-9041;
e-mail: len48@inbox.ru

*** Жахонгир Одил угли Рахмонов**, аспирант;
адрес: Россия, 197022, Санкт-Петербург, ул. Льва Толстого, д. 6–8;
ORCID: 0009-0005-9176-0156;
e-mail: janik.27@mail.ru

* Corresponding author / Автор, ответственный за переписку