

FLUORESCENCE-GUIDED SURGERY FOR THE MANAGEMENT OF THYROID AND PARATHYROID NEOPLASMS: THE ROLE OF A MODERN METHOD IN PREVENTION OF DISABLING COMPLICATIONS¹Bogomolets National Medical University (Kyiv, Ukraine)²Kyiv Agrarian University (Kyiv, Ukraine)

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Surgical management of malignant and benign lesions of the thyroid and parathyroid glands remains the cornerstone procedure. Although surgical management of these neoplasms is well-established techniques with good history of its improvement, it is associated with some risks of disabling complications such as postoperative hypoparathyroidism and recurrent laryngeal nerve (RLN) palsy. Although high-differentiated thyroid carcinomas retain favorable cure rates with surgery (often combined with radioiodine), extensive procedures (thyroidectomy and neck dissections) increase the likelihood of unintentional parathyroid damage and RLN impairment. Reoperative neck surgery is particularly challenging due to distorted anatomy after the previous procedures as well as significant scar tissue, elevating the risk of misidentifying parathyroid glands and metastatic lymph nodes. It is surgical catastrophe to consider metastatic lymph node as a parathyroid gland and skip its dissection. In this matter, fluorescence-guided surgery (FGS) might be a useful intraoperative tool to discriminate parathyroid glands from other structures and keep them intact. FGS is based on detection of parathyroid autofluorescence in the near-infrared range (~740–820 nm) and signal enhancement with indocyanine green (ICG), is an emerging adjunct for intraoperative identification. A literature review (PubMed, Scopus, Google Scholar; English and Ukrainian sources) indicates that FGS systems (Fluobeam, PTEye, EleVision, etc.) improve parathyroid visualization and reduce inadvertent gland excision and rates of transient and permanent hypoparathyroidism. Combining FGS with IONM yields a synergistic effect in decreasing RLN injury risk, as ICG angiography can delineate vascular anatomy around the nerve and assist localization. Limitations include equipment cost, need for procedural standardization, variability in autofluorescence intensity, and the requirement for further multicenter trials to assess long-term clinical outcomes. FGS represents a promising adjunct in endocrine surgery with potential to reduce disabling complications in thyroid and parathyroid operations; further standardized research is required to optimize its clinical application.

Key words: recurrent laryngeal nerve, autofluorescence of parathyroid glands, fluorescence-guided surgery, indocyanine green, thyroid surgery, parathyroid surgery, prevention of postoperative complications.

Connection of the publication with planned research work.

The work does not have connection with planned research works.

Introduction.

Surgical treatment is primary approach to treat malignant and benign thyroid and parathyroid neoplasms. The incidence of thyroid cancer remains stable with mean frequency of 1.7–2.2% out of all malignant thyroid tumors, and these are mainly highly thyroid differentiated carcinomas (follicular cancer, papillary cancer). The surgical treatment of these malignant neoplasms, with or without radioiodine therapy, allows to ensure the cure of patients in 95–99% of cases [1]. Primary hyperparathyroidism (PHPT) is result of parathyroid adenoma, and it is the most underdiagnosed disease, mainly due to the variability of the clinical picture. PHPT is diagnosed by laboratory funding and the treatment is surgical [2–5]. Diagnosis of thyroid cancer includes instrumental, cytological, and molecular genetic methods, as described in the current 2025 guideline of the American Thyroid Association, numerous scientific publications by domestic and foreign scientists and practitioners [4–6]. Despite surgical interventions on the thyroid and parathyroid glands using capsular dissection methods to ensure extrafascial removal of tumors, the risk of damage to vital neck structures is high, but the real incidence of the complications is usually low among skilled endocrine surgeons. Bleeding, recurrent laryngeal

nerve (RLN) palsy, and unintentional removal of the parathyroid glands are considered as disabling complications, minimizing the frequency of which is an urgent task for endocrine surgeons worldwide, and including Ukraine [7, 8]. The risks of RLN and parathyroid gland involvement are higher in thyroid cancer surgery, where thyroidectomy or hemithyroidectomy are the standard according to current guidelines. Usually, the neck dissection is performed for a central compartment (6–7 neck compartments), even in the absence of reliable data on metastatic lesions. With the indicated volumes of surgery, but mainly with thyroidectomy, the risk of both persistent hypoparathyroidism and RLN palsy increases [9]. Another problematic issue in endocrine surgery is repeated neck surgeries for recurrent thyroid cancer or primary hyperparathyroidism, when after primary surgeries there is a violation of normal anatomical landmarks and a pronounced splenic process, which is associated with an even higher risk of both RLN and parathyroid glands, which can be confused with metastatic lymph nodes [10]. And if for verification of RLN it is possible to use intraoperative neuromonitoring (IONM) to reduce the risk of nerve damage, then visualization and verification of parathyroid glands during repeated neck surgeries is a more complex issue. Available visualization techniques – computed tomography (CT) or ultrasound (US) do not provide reliable data that would indicate intraoperatively a clear localization of RLN and parathyroid glands. Considering the above-mentioned problematic

issues of endocrine surgery, and surgery of the thyroid and parathyroid glands, the current direction is the use of hardware techniques for intraoperative identification and verification of RLN and parathyroid glands, as an additional tool to the naked eye of the surgeon. The latest trend that has revolutionized the intraoperative detection of parathyroid glands, and according to some reports also RLN, is fluorescence-guided surgery (FGS). FGS uses the properties of tissues to synthesize a signal with a certain wavelength, record it using special devices and thereby identify the target tissue among other tissues during operations. In the context of endocrine surgery, FGS has been actively developed for the detection of parathyroid glands since 2011, when their ability to autofluorescence (the property of synthesizing a signal in the near-infrared range) was discovered [11]. The infrared spectrum with a wavelength of 740–820 nm, which is characteristic of the parathyroid glands, can be detected by special equipment, with the possibility of contrast enhancement with fluorophore agents such as indocyanine green (ICG). Another possible point of application of FGS in endocrine surgery is the performance of angiography of RLN vessels, which can be an additional intraoperative tool for identifying RLN. In Ukraine, FGS in endocrine surgery is in the process of implementation and research, which necessitates the need to systematize the accumulated data on this part of surgery.

The aim of the study.

To conduct a literature review of national and international studies, and to analyze and substantiate the indications and features of the use of fluorescence-guided surgery in the surgical treatment of thyroid and parathyroid tumors.

Object and research methods.

Electronic databases of medical publications PubMed, Google Scholar, Scopus were used to search for scientific articles. The search was used for English-language publications in PubMed, Google Scholar, Scopus, and for Ukrainian-language publications in Google Scholar. The search used the following keywords: thyroid cancer and fluorescence-guided surgery, parathyroid adenoma and fluorescence-guided surgery, complications of thyroid surgery, fluorescence-guided surgery and thyroid cancer, fluorescence-guided surgery and parathyroid adenoma, complication of thyroid surgery. According to the results of the literature search, the most significant articles were selected that meet the modern scientific and practical standard for the treatment of surgical pathology of the thyroid and parathyroid glands.

Main part.

Fluorescence-guided surgery devices and operating principle.

The autofluorescent properties of tissues are based on the physical properties of synthesizing a signal with a certain wavelength, which is possible for detection by special equipment [12, 13]. Fluorescence imaging involves a sequence of actions that use equipment to act on the area of interest by directing a light source of a specific wavelength at it, resulting in this light being absorbed by the target tissue, emitting a longer wavelength in response, which can be recorded by a specially designed camera for the specific wavelength [14–16]. In fluorescence-guided surgery, the near-infrared region is often used, as it is characterized by deeper tissue penetration of up to 10 mm, which is a sufficient

depth parameter for assessing the fluorescence signal, for example, when using this technique to assess lymph nodes affected by metastatic processes, as well as when searching for parathyroid adenomas [12, 17, 18]. One may compare near-infrared with ultraviolet spectrum (wavelength 200–650 nm), having sufficient penetration into tissues does not occur or a reaction with endogenous fluorophores is observed, and therefore it is impossible to reliably clearly distinguish the signal of the target tissue from other tissues (which actually create a “curtain” for the target signal), and this, accordingly, reduces the diagnostic value of the use of ultraviolet radiation [19]. Thus, the infrared area is most optimal for use in fluorescence-guided surgery, and fluorescence imaging systems are optimized for wavelengths in the range of 720–850 nm. This range of infrared radiation provides sufficient intensity and specificity of the signal intraoperatively in real time for the identification and verification of parathyroid glands, with the possibility of their differentiation from other tissues, including metastatic lymph nodes, as shown in published studies [12, 14, 17, 18, 20]. Among the various fluorescence-guided surgery devices, the common is the PTeye, which provides visualization and audio signal when a hand-held probe contacts the parathyroid gland. The PTeye is equipped with a light source that produces a beam in the near infrared region and is also equipped with a camera to identify tissue autofluorescence, the signal being fed to a monitor [21, 22]. Also there are the devices namely PDE Neo II, EleVision IR Platform, demonstrating similar technical characteristics. A similar principle is used in other devices that are more often used in endocrine surgery centers in Ukraine: Fluobeam-800/Fluobeam-LX (Fluoptics). According to original publications by Ukrainian researchers, Fluobeam-800/Fluobeam-LX allow to significantly improve the results of treatment of patients with malignant and benign diseases of the thyroid and parathyroid glands, in particular to reduce the frequency of disabling complications - unintentional removal of the parathyroid glands or assessment of metastatic lymph nodes as parathyroid glands [13, 15, 23, 24]. The latter can have catastrophic consequences in the form of further spread of thyroid cancer metastases. In Ukraine, a prototype of a domestic apparatus for fluorescence-guided surgery was also presented, and the surgical research group of Gorobeiko et al. proposed the use of a hardware technique based on the ability of the parathyroid glands to synthesize a signal in the near infrared region.

The role of fluorescence-guided surgery in reducing the incidence of postoperative hypoparathyroidism.

Thyroid surgery is characterized by transient hyperparathyroidism in 15–20% of patients, with thyroidectomy for thyroid cancer, while the risk of permanent hypoparathyroidism is reported to be 2–3% of patients [9, 23, 25]. However, a review of published articles, including systematic reviews and meta-analyses, suggests a relatively high incidence of transient hypoparathyroidism (25–27%) and a relatively low incidence of permanent hypoparathyroidism (0.5–1%) following surgery for malignant and benign thyroid nodules. The authors note a higher incidence of complications in thyroid and parathyroid surgery with a higher volume of surgery than thyroidectomy, with central and/or lateral neck dissection being associated with a higher incidence of hyperparathyroidism [9, 23, 26, 27]. Studies show tran-

sient hypoparathyroidism in 25–28% of patients undergoing surgery for parathyroid disease, with 0.2–14% of patients having permanent hypoparathyroidism with severe or moderate hypocalcemia, according to previously published data [28]. Although the vast majority of cases of postoperative hypoparathyroidism are temporary and resolve within 6 months after surgery, a small percentage of patients require lifelong calcium and active forms of vitamin D (calcitriol, etc.), which is a significant factor that negatively affects quality of life [29]. Thus, the development and implementation of new techniques and hardware methods that would reduce the risks of such a postoperative complication as hypoparathyroidism is an extremely relevant and important direction of endocrine surgery. In this regard, fluorescence-guided surgery (FGS) with determination of autofluorescence of parathyroid glands in native or with the use of fluorophore enhancement, in particular indocyanine green (ICG), demonstrates a lower frequency of these complications even in highly specialized centers of endocrine surgery [12, 16, 30, 31]. Also, it might be considered possible application of artificial intelligence (AI) tools for the evaluations of the signals from ICG, as it was suggested in various review and translational papers [32–34].

The role of fluorescence-guided surgery in reducing the incidence of recurrent laryngeal nerve injury.

The recurrent laryngeal nerve (RLN) is a branch of the vagus nerve and plays a vital role in innervating almost all muscles of the larynx except the cricothyroid muscle. The RLN provides phonation and respiration. Thus, RLN damage is considered a disabling complication that leads not only to impaired phonation, but can also be associated with impaired respiratory function, hoarseness, stridor, and dysphagia. RLN damage can occur during thyroid surgery, as the nerve passes in the trachea near the Zuckerkandl tubercle and is associated with the Berry ligament, which is taken into account during mobilization of thyroid lobes. However, given the intimate attachment of the RLN to the thyroid structures, technical difficulties in isolating the RLN are often reported in cases of widespread PTC, invasion of carcinomas into the nerve area, or tight attachment of the RLN to the

thyroid capsule in benign neoplasms. According to the literature, the risk of bilateral RLN involvement and vocal cord paralysis may be associated with surgical trauma in 20–44% of cases, malignant neoplasms in 10–17%, and up to 15% of cases due to trauma during endotracheal intubation [35]. Tools for more reliable visualization and verification of peripheral nerves are often used in surgery. But these are mainly intraoperative neuromonitoring systems (IONM), which are also common in thyroid surgery [36]. But improving the results of surgical treatment of patients with malignant and benign thyroid tumors, as well as parathyroid adenomas, can also be achieved by combining IONM with FGS instruments [14, 18]. According to the publication, a possible point of application of FGS to IONM is the possibility of its use for identification and verification of peripheral nerves, in particular the RLN, the lesion of which is also considered a disabling complication. It is reported that the simultaneous use of IONM and ICG-enhanced angiography of the RLN is associated with more reliable identification and verification of the RLN. The authors present a series of patients who were applied to this approach, which allowed to improve the results of surgical treatment [14, 18].

Conclusions.

Fluorescence-guided surgery is a novel surgical method that is of great importance in performing surgical interventions for thyroid and parathyroid pathology; it improves the results of surgical treatment of patients with thyroid cancer and parathyroid adenomas by reducing the risk of disabling complications - damage to the RLN or inadvertent removal of the parathyroid gland. It is advisable to enhance the autofluorescence signal of the parathyroid glands using the fluorophore agent ICG.

Prospects for further research.

The routine application of FGS in thyroid surgeries will determine the further development of endocrine surgery in Ukraine, which requires the development of optimal algorithms for the use of FGS to select approaches to the surgical treatment of thyroid tumors, including malignant ones, as well as the surgical treatment of adenomas and carcinomas of the parathyroid glands.

References

- Dinets A, Gorobeiko M, Lovin A, Dibrova V, Hoperia V. Psammoma bodies in lymph nodes of the neck: possible precursor of locoregional metastases of papillary thyroid carcinoma. *Exp Oncol.* 2024;46(1):61-7. DOI: <https://doi.org/10.15407/exp-oncology.2024.01.061>
- Cherenko SM, Dinets A, Bandura GV, Sheptuha SA, Larin SO. Multiglandular parathyroid gland disease: an incidental discovery in normocalcemic patients during thyroid surgery. *Acta Endocrinologica.* 2017;8(3):349-55. DOI: <https://doi.org/10.4183/aeb.2017.349>
- Gorobeiko M, Dinets A, Pominchuk D, Abdalla K, Prylutsky Y, Hoperia V. Challenges of Differential Diagnosis Between Primary Hyperparathyroidism and Bone Metastases of Breast Cancer. *Clin Med Insights Case Rep.* 2022;15:11795476221125136. DOI: <https://doi.org/10.1177/11795476221125136>
- Haglund F, Rosin G, Nilsson IL, Juhlin CC, Pernow Y, Norenstedt S, et al. Tumour nuclear oestrogen receptor beta 1 correlates inversely with parathyroid tumour weight. *Endocr Connect.* 2015;4(1):76-85. DOI: <https://doi.org/10.1530/ec-14-0109>
- Haglund F, Juhlin CC, Brown T, Ghaderi M, Liu T, Stenman A, et al. TERT promoter mutations are rare in parathyroid tumors. *Endocr Relat Cancer.* 2015;22(3):L9-L11. DOI: <https://doi.org/10.1530/erc-15-0121>
- Ringel MD, Sosa JA, Baloch Z, Bischoff L, Bloom G, Brent GA, et al. 2025 American Thyroid Association Management Guidelines for Adult Patients with Differentiated Thyroid Cancer. *Thyroid.* 2025;35(8):841-985. DOI: <https://doi.org/10.1177/10507256251363120>
- Alshehri S, Alsarrani F, Aldrees A, Alotaibi A, Alsadun S, Almalik A. Unexpected postoperative incidental recurrent laryngeal nerve palsy post total thyroidectomy after intraoperative nerve monitoring (overstimulation and fatigability): a case report. *J Med Case Rep.* 2025;19(1):82. DOI: <https://doi.org/10.1186/s13256-025-05079-4>
- Ballabh M, Ganesan S, Parasuraman L, Karthik V G, Parthasarathy I. Outcomes of Prophylactic Central Neck Dissection in Clinically Node-Negative Papillary Thyroid Carcinoma: A Retrospective Study From a Tertiary Care Centre. *Cureus.* 2025;17(5):e84879. DOI: <https://doi.org/10.7759/cureus.84879>
- Sim M, Tan E, Liew H, Tan A, Li H. Total Thyroidectomy and Quality of Life in Patients With Hashimoto Thyroiditis: A Systematic Scoping Review. *J Surg Res.* 2025;316:185-95. DOI: <https://doi.org/10.1016/j.jss.2025.10.041>
- Gorobeiko M, Dinets A, Hoperia V, Abdalla K. Improved intraoperative verification of parathyroid glands by determining their autofluorescence in the infrared spectrum. *International journal of endocrinology (Ukraine).* 2021;17(6):465-71.
- Priyanka S, Sam ST, Rebekah G, Sen S, Thomas V, Wankhar S, et al. The utility of indocyanine green (ICG) for the identification and assessment of viability of the parathyroid glands during thyroidectomy. *Updates Surg.* 2022;74(1):97-105. DOI: <https://doi.org/10.1007/s13304-021-01202-4>

12. Karcioğlu AS, Hartl D, Shonka DC, Slough CM, Stack BC, Tolley N, et al. Autofluorescence of Parathyroid Glands: A Review of Methods of Parathyroid Gland Identification and Parathyroid Vascular Assessment. *Otolaryngol Clin North Am.* 2024;57(1):139-54. DOI: <https://doi.org/10.1016/j.otc.2023.07.011>
13. Grubnik VV, Parfentiev RS, Grubnik YV, Grubnyk VV. Intraoperative indocyanine green angiography for predicting postoperative hypoparathyroidism. *Surg Endosc.* 2023;37(12):9540-5. DOI: <https://doi.org/10.1007/s00464-023-10466-3>
14. Gorobeiko M, Dinets A. Unexpected mapping of recurrent laryngeal nerve by fluorescence-guided surgery using near-infrared indocyanine green angiography. *Miznarodnij Endokrinologichnij Zurnal.* 2023;19(5):349-53. DOI: <https://doi.org/10.22141/2224-0721.19.5.2023.1298>
15. Gorobeiko M, Dinets A. Intraoperative detection of parathyroid glands by autofluorescence identification using image-based system: report of 15 cases. *J Med Case Rep.* 2021;15(1):414. DOI: <https://doi.org/10.1186/s13256-021-03009-8>
16. Stewart HL, Birch DJS. Fluorescence Guided Surgery. *Methods Appl Fluoresc.* 2021;9(4). DOI: <https://doi.org/10.1088/2050-6120/ac1dbb>
17. Abe K, Takahashi T, Yokoyama Y, Shodo R, Ueki Y, Yamazaki K, et al. Near-Infrared Autofluorescence Identification of Ectopic Parathyroid Lesions. *Laryngoscope.* 2024;134(1):496-500. DOI: <https://doi.org/10.1002/lary.30728>
18. Gorobeiko M, Dinets A. The role of fluorescence-guided surgery for the verification of parathyroid glands and recurrent laryngeal nerves in the near infrared spectrum. *Bulletin of problems in biology and medicine.* 2023;2(169):196-200. DOI: <http://dx.doi.org/10.29254/2077-4214-2023-2-169-196-200>
19. van Manen L, Handgraaf HJM, Diana M, Dijkstra J, Ishizawa T, Vahrmeijer AL, et al. A practical guide for the use of indocyanine green and methylene blue in fluorescence-guided abdominal surgery. *J Surg Oncol.* 2018;118(2):283-300. DOI: <https://doi.org/10.1002/jso.25105>
20. Lu D, Pan B, Tang E, Yin S, Sun Y, Yuan Y, et al. Intraoperative strategies in identification and functional protection of parathyroid glands for patients with thyroidectomy: a systematic review and network meta-analysis. *Int J Surg.* 2024;110(3):1723-34. DOI: <https://doi.org/10.1097/js9.0000000000000991>
21. Law RH, Larrabee KA, Van Harn M, Singer MC. Parathyroid Gland Autofluorescence Characteristics in Patients With Primary Hyperparathyroidism. *Laryngoscope.* 2022;132(3):715-21. DOI: <https://doi.org/10.1002/lary.29880>
22. Thomas G, Solorzano CC, Baregamian N, Mannoh EA, Gautam R, Irlmeier RT, et al. Comparing intraoperative parathyroid identification based on surgeon experience versus near infrared autofluorescence detection - A surgeon-blinded multi-centric study. *Am J Surg.* 2021;222(5):944-51. DOI: <https://doi.org/10.1016/j.amjsurg.2021.05.001>
23. Bergenfelz A, Barczynski M, Heie A, Muth A, Passler C, Schneider M, et al. Impact of autofluorescence for detection of parathyroid glands during thyroidectomy on postoperative parathyroid hormone levels: parallel multicentre randomized clinical trial. *Br J Surg.* 2023;110(12):1824-33. DOI: <https://doi.org/10.1093/bjs/znad278>
24. Obongo Anga R, Abbaci M, Guerlain J, Breuskin I, Casiraghi O, Marhic A, et al. Intraoperative Autofluorescence Imaging for Parathyroid Gland Identification during Total Laryngectomy with Thyroidectomy. *Cancers (Basel).* 2023;15(3). DOI: <https://doi.org/10.3390/cancers15030875>
25. Kannan T, Foster Y, Ho DJ, Gelzinnis SJ, Merakis M, Balogh ZJ, et al. Post-Operative Permanent Hypoparathyroidism and Preoperative Vitamin D Prophylaxis. *J Clin Med.* 2021;10(3). DOI: <https://doi.org/10.3390/jcm10030442>
26. Rao SS, Rao H, Moinuddin Z, Rozario AP, Augustine T. Preservation of parathyroid glands during thyroid and neck surgery. *Front Endocrinol (Lausanne).* 2023;14:1173950. DOI: <https://doi.org/10.3389/fendo.2023.1173950>
27. Vabalayte K, Romanchishen A, Somova A. Intraoperative prevention of postoperative hypoparathyroidism. *Front Endocrinol (Lausanne).* 2023;14:1206881. DOI: <https://doi.org/10.3389/fendo.2023.1206881>
28. Chahardahmasumi E, Salehidoost R, Amini M, Aminoroaya A, Rezvanian H, Kachoei A, et al. Assessment of the Early and Late Complication after Thyroidectomy. *Adv Biomed Res.* 2019;8:14. DOI: https://doi.org/10.4103/abr.abr_3_19
29. Lee YS, Nam KH, Chung WY, Chang HS, Park CS. Postoperative complications of thyroid cancer in a single center experience. *J Korean Med Sci.* 2010;25(4):541-5. DOI: <https://doi.org/10.3346/jkms.2010.25.4.541>
30. Johnston ME, Farooqui ZA, Nagarajan R, Pressey JG, Turpin B, Dasgupta R. Fluorescent-guided surgery and the use of indocyanine green sentinel lymph node mapping in the pediatric and young adult oncology population. *Cancer.* 2023;129(24):3962-70. DOI: <https://doi.org/10.1002/cncr.35023>
31. Hom ME, Rosenthal EL, Varvares M. The Future of Fluorescent-Guided Surgery. *JAMA Otolaryngol Head Neck Surg.* 2021;147(10):920.
32. Milford EM, Gurney JM, Beckett A, Strandenes G, Reade MC. Type-specific whole blood still has a role in the era of low-titer O universal donor transfusion for severe trauma hemorrhage. *J Trauma Acute Care Surg.* 2024;97(3):e23-e7. DOI: <https://doi.org/10.1097/ta.0000000000004369>
33. Lurin I, Gorobeiko M, Lovin A, Gorobeiko B, Lovina N, Dinets A. Application of artificial intelligence in civil and military medicine. *Georgian Med News.* 2024(348):94-8.
34. Lurin I, Gorobeiko M, Usenko OY, Khoroshun E, Makarov V, Nehoduiko V, et al. A review of the artificial intelligence application as a guideline tool for the wound management. *Emergency medicine.* 2024;20(5):417-22.
35. Kofopoulos-Lymeris E, Stavratsi K, Papaconstantinou D, Pikoulis E, Peppas M, Chaidas K, et al. Beyond Surgical Injury: Systemic Etiologies of Recurrent Laryngeal Nerve Palsy. *In Vivo.* 2025;39(6):3090-105. DOI: <https://doi.org/10.21873/invivo.14111>
36. Brunet A, Rovira A, Quer M, Sanabria A, Guntinas-Lichius O, Zafereo M, et al. Recurrent Laryngeal Nerve Intraoperative Neuromonitoring Indications in Non-Thyroid and Non-Parathyroid Surgery. *J Clin Med.* 2024;13(8):2221. DOI: <https://doi.org/10.3390/jcm13082221>

ФЛУОРЕСЦЕНТ-КЕРОВАНА ХІРУРГІЯ В ЛІКУВАННІ ПУХЛИН ЩИТОПОДІБНОЇ ТА ПРИЩИТОПОДІБНОЇ ЗАЛОЗИ: РОЛЬ СУЧАСНОГО МЕТОДУ В МІНІМІЗАЦІЇ ІНВАЛІДИЗУЮЧИХ УСКЛАДЕНЬ

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Резюме. Хірургічне лікування доброякісних та злоякісних пухлин щитоподібної та прищитоподібних залоз було і залишається основним видом лікування, але несе ризики серйозних ускладнень, пов'язаних з ризиком інвалідації пацієнтів. До цих ускладнень належать кровотеча, ураження зворотного гортанного нерва (ЗГН), а також післяопераційний гіпаратиреоз. Ураження ЗГН та післяопераційний гіпаратиреоз рідко зустрічаються серед ендокринних хірургів, які виконують велику кількість операцій, проте їх ризик все ще враховується у складних випадках. Варто зазначити, що навіть добре диференційований рак щитоподібної залози (який часто має хороші результати після хірургічного втручання) вимагає обширних хірургічних процедур (тотальної тиреоїдектомії та дисекції шиї), що збільшує ймовірність травми парашитоподібних залоз та пошкодження ЗГН. Повторні операції на шиї є особливо небезпечними, оскільки рубцювання та змінені анатомія ускладнюють диференціацію прищитоподібних залоз від метастатичних вузлів. Традиційні інтраопераційні допоміжні засоби, такі як інтраопераційний нейромоніторинг (ІОНМ) та передопераційна візуалізація (КТ, УЗД) для кращого планування, обмежені щодо надійної локалізації тканини прищитоподібних залоз та візуалізації ЗГН. Флуоресцентно-керована хірургія (ФКХ), що використовує власну аутофлуоресценцію прищитоподібних залоз у ближньому інфрачервоному спектрі та посилений сигнал флуорофором індоціанінового зеленого (ICG). ФКР розглядається як інтраопераційне доповнення до традиційних операцій на щитоподібній та прищитоподібних залозах. Огляд англійської та української наукової літератури (PubMed, Scopus, Google Scholar) показує, що системи ФКХ (наприклад, Fluobeam, PTeve, EleVision) покращують ідентифікацію прищитоподібних

залоз та зменшують їх випадкове видалення, а також частоту транзиторного та постійного гіпаратиреозу. У поєднанні з ІОНМ, ФКХ, здається, ще більше знижує ризик пошкодження прищитоподібних залоз, оскільки ICG-ангіографія допомагає картувати судинну анатомію поблизу нерва та сприяє кращій візуалізації. Недоліки включають вартість обладнання, відсутність стандартизованих протоколів, мінливість аутофлуоресцентного сигналу та необхідність багаточисельних досліджень для визначення довгострокових результатів. ФКХ є перспективним доповненням в ендокринній хірургії шиї з потенціалом для зменшення інвалідизуючих ускладнень, але для оптимізації його клінічного використання необхідні стандартизовані дослідження.

Ключові слова: поворотний гортанний нерв; аутофлуоресценція прищитоподібних залози; флуоресцент-керована хірургія; індоціанін зелений; хірургія щитоподібної залози, хірургія прищитоподібних залоз; профілактика післяопераційних ускладнень

FLUORESCENCE-GUIDED SURGERY FOR THE MANAGEMENT OF THYROID AND PARATHYROID NEOPLASMS: THE ROLE OF A MODERN METHOD IN PREVENTION OF DISABLING COMPLICATIONS

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Abstract. Surgical treatment of benign and malignant thyroid and parathyroid lesions was and remains the primary therapy, but carries risks of serious complications to be associated with risk of patients disabilities. Of these complications, there are bleeding, palsy of recurrent laryngeal nerve (RLN) as well as postoperative hypoparathyroidism. The RLN palsy and postoperative hypoparathyroidism are rare among high-volume endocrine surgeons, however its risk is still considered in complicated cases. It is worth to mention that even well-differentiated thyroid cancers (which often have good outcomes with surgery), require extensive procedures (total thyroidectomy and neck dissection) that increase the chance of parathyroid trauma and RLN damage. Reoperative neck surgery is especially hazardous because scarring and altered anatomy make it harder to distinguish parathyroid glands from metastatic nodes. Traditional intraoperative aids are intraoperative neuromonitoring (IONM) and preoperative imaging (CT, ultrasound) for the better planning, are limited in reliably localizing parathyroid tissue and visualizing the RLN. Fluorescence-guided surgery (FGS), exploiting intrinsic parathyroid autofluorescence in the near-infrared spectrum and enhanced signal with indocyanine green (ICG) fluorophore. FGS is emerged as an intraoperative adjunct for the conventional thyroid and parathyroid surgeries. A review of English and Ukrainian research literature (PubMed, Scopus, Google Scholar) shows that FGS systems (e.g., Fluobeam, PTeye, EleVision) improve identification of parathyroid glands and reduce inadvertent excision and rates of transient and permanent hypoparathyroidism. When combined with IONM, FGS appears to further lower RLN injury risk, as ICG angiography helps map vascular anatomy near the nerve and aid localization. Drawbacks include equipment costs, lack of standardized protocols, variability in autofluorescence signal, and the need for multicenter trials to define long-term outcomes. FGS is a promising adjunct in endocrine neck surgery with potential to lessen disabling complications, but standardized research is needed to optimize its clinical use.

Key words: recurrent laryngeal nerve, autofluorescence of parathyroid glands, fluorescence-guided surgery, indocyanine green, thyroid surgery, parathyroid surgery, prevention of postoperative complications.

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Conflict of interest:

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A – Work concept and design, B – Data collection and analysis, C – Responsibility for statistical analysis, D – Writing the article, E – Critical review, F – Final approval of the article.

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