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APPLICATION OF NEUROMONITORING IN THE PRACTICE OF THYROID SURGERY

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Actuality. Systematic reviews and meta-analyses of studies comparing intervention with intraoperative neuromonitoring with the identification of recurrent laryngeal nerve in the absence of intraoperative neuromonitoring have been published. Data from these reviews are conflicting. Some authors insist that intraoperative neuromonitoring reduces both temporary and permanent damage to the recurrent laryngeal nerve. Other researchers did not find a significant reduction in the frequency of damage to the recurrent laryngeal nerve, instead, they indicate a greater comfort for the surgeon when performing the intervention.

The purpose of the review was to assess the main trends in the use of neuromonitoring in thyroid surgery.

Material and methods. The information search was carried out in PubMed, EMBASE, Ovid EBMR, UpToDate, Cochrane Library databases. Search depth – 5 years. Key words were "intraoperative neuromonitoring", "thyroid surgery", "recurrent laryngeal nerve". 67 sources were analyzed, from which 29 publications were selected for further analysis.

Results and discussion. The epidemiology of traumatic laryngeal nerve injuries, their etiology and clinical manifestations are considered. The most common mechanisms of recurrent laryngeal nerve injury are traction (for example, during removal of a retrosternal goiter); incision or electrocoagulation is much less common. The history of the development of the issue, modern trends in the application of intraoperative monitoring have been studied.

The advantages of using intraoperative monitoring for identification of laryngeal nerves over conventional imaging are discussed. It is shown that the efficiency of identification of the recurrent laryngeal nerve reaches 98–100%. It is emphasized that the introduction of intraoperative monitoring into surgical practice in the treatment of thyroid gland diseases prevents trauma to the thyroid gland and improves the life quality.

Key words: intraoperative monitoring, prevention of complications, thyroid surgery.

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ЗАСТОСУВАННЯ НЕЙРОМОНІТОРИНГУ В ПРАКТИЦІ ТИРЕОЇДНОЇ ХІРУРГІЇ
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Огляд присвячено застосуванню інтраопераційного моніторингу у сучасній тиреоїдній хірургії. Розглянуті питання епідеміології травматичних ушкоджень нервів гортані, їх етіологію та клінічні прояви, історію розвитку питання, сучасні тенденції у застосуванні інтраопераційного моніторингу. Обговорено переваги застосування інтраопераційного моніторингу для ідентифікації нервів гортані над звичайною візуалізацією. Показано, що ефективність ідентифікації зворотного гортанного нерва сягає 98–100%. Наголошується, що впровадження інтраопераційного моніторингу у хірургічну практику під час лікування захворювань щитовидної залози запобігає травмуванню ЗГН та ЗГВГН, а також покращує якість життя пацієнтів.

Ключові слова: інтраопераційний моніторинг, профілактика ускладнень, тиреоїдна хірургія.

The incidence of temporary recurrent laryngeal nerve (RLN) palsy ranges from 2% to 13%, and permanent palsy from 0.4% to 5.2% after thyroidectomy [1; 2]. In their time, Lahey and Hoover revolutionized thyroid surgery by promoting routine identification of RLN, direct imaging of RLN, and capsular dissection, which has become the gold standard for the prevention of traumatic paresis during thyroid surgery [2]. Despite careful visual identification of the RLN, damage to it can still occur due to anatomical changes, surgeon inexperience, and complex situations, including large goiter, revision surgery, and the presence of invasive malignancy [3]. The main disadvantage of simple visualization is the surgeon's inability to predict the functional integrity of a visually intact nerve. Possible mechanisms of injury to the RLN include not only transection but also compression, ligation, traction, thermal injury, and ischemia [4].

The use of intraoperative neuromonitoring (IONM) during thyroidectomy allows to confirm the functional integrity of the RLN and facilitates its identification before visualization during surgery, especially in high-risk situations [5–7]. In this context, it was expected that monitoring of both evoked and spontaneous electromyographic activity of the vocal cord should significantly reduce the incidence of RLN lesions.

As the volume of thyroid surgery has increased in recent years, so have the risk minimization measures to protect the RLN (Fig. 1). Although the incidence of traumatic paresis of the RLN is low in experienced hands, voice changes, especially if they are permanent, significantly impair the patient's quality of life [4; 8]. IONM includes three interdependent stages of nerve assessment: preoperative, intraoperative, and postoperative monitoring of the function of the RLN [5]. Perfect surgical skills, including visual identification and dissection of the RLN along its anatomical course, are an important prerequisite for successful thyroid surgery.

Despite the fact that the use of IONM is gaining popularity and is considered a standard of care in some countries, the cost-effectiveness of this technology remains controversial [9].

Many systematic reviews and meta-analyses have been published comparing interventions with IONM with identification of RLN in the absence of IONM [5–7; 10; 11]. The findings of these reviews are contradictory. Some authors insist that IONM reduces both temporary and permanent damage to the RLN. Other researchers have not found a significant reduction in the incidence of RLN damage, but instead indicate greater comfort for the surgeon during the intervention.

The aim of the review was to assess the main trends in the use of neuromonitoring in thyroid surgery.

Material and methods. An information search was conducted in PubMed, EMBASE, Ovid EBMR, UpToDate, and Cochrane Library databases. The depth of the search was 5 years. Key words were "intraoperative neuromonitoring", "thyroid surgery", "recurrent laryngeal nerve".

We analyzed 67 sources, of which 29 publications were selected for further analysis.

Results and discussion. The most common mechanism of injury to the recurrent laryngeal nerve is traction (e.g., during removal of a sternal goiter); direct mechanical damage (incision, incision) or electrocoagulation as a cause of injury are much less common. Jeannon et al. showed, based on a review of 27 studies analyzing more than 25.000 thyroid surgeries, that the average incidence of paralysis of RLN was 9.8%. The complication rate was 2.3–26% [12]. This large discrepancy is due to many factors; secondary thyroid, large goiter, and sternocleidomastoid surgeries, as well as thyroid cancer and Graves' disease surgeries, have a higher complication rate than multinodular goiter surgeries [13]. In addition, the incidence of RLN involvement depends on the number of laryngeal examinations after thyroidectomy, which are not regularly performed in all surgical departments.

Damage to the external branch of the superior laryngeal nerve (EBSLN) can occur in 58% of patients [14–16].

Cernea classification is the most common and widely recognized anatomical classification of the risk of injury during thyroidectomy. This classification is as follows: Type 1: EBSLN crosses the superior thyroid artery more than 1 см above the upper edge of the upper thyroid pole and is common in 68% of patients with a small goiter and 23% of patients with a large goiter. Type 2A: the nerve crosses the superior vessels less than1 см above the upper edge of the upper pole; it is recognized in 18% of patients with a small goiter and 15% of patients with a large goiter. Type 2B: EBSLN crosses the upper thyroid vessels below the upper edge of the upper pole of the thyroid gland. Typically, type 2B occurs in 14% of patients with a small goiter and 54% of patients with a large goiter. Type 2B is the most susceptible to trauma. Visual identification of EBSLN may not be possible in 20% of patients when the nerve is located deep in the fascia of the lower constrictor muscle [17].

Unilateral RLN paralysis most often leads to hoarseness or voice tone or swallowing disorders, while bilateral damage can lead to dyspnea and acute respiratory failure, which can be life-threatening [18]. This condition often requires tracheostomy. In more than 20% of patients, vocal cord paralysis due to RLN injury can be asymptomatic; therefore, laryngoscopy is the only objective tool to correctly assess the percentage of RLN paralysis and should always be performed both before and after thyroid surgery [4; 19].

In the case of damage to the EBSLN, the most underestimated complication of thyroid surgery, the patient cannot produce high pitched sounds and the voice weakens during modulation, which is important for people who work with voice [8; 19]. Clinically, patients with damage to the EBSLN have a hoarse or weak voice. These symptoms are the result of dysfunction of the cricothyroid muscle, which is innervated by the EBSLN [14]. Damage to this nerve is difficult to detect during a routine postoperative laryngoscopy, and both the Voice Hearing Impairment Index (VHI) and the Voice-Related Quality of Life (V-RQOL) are validated tools for assessing voice quality and risk of EBSLN injury [4].

As early as 1938, one of the pioneers of thyroid surgery, Frank Lahey, observed on the basis of more than 3000 thy-

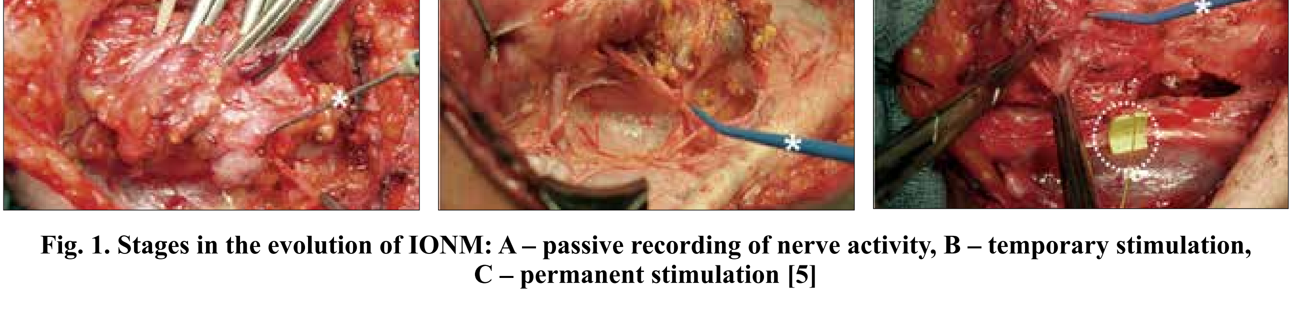

Fig. 1. Stages in the evolution of IONM: A – passive recording of nerve activity, B – temporary stimulation, C – permanent stimulation [5]

roidectomies performed that routine identification of the RLN during thyroid surgery reduces the incidence of thyroid injury [19]. Currently, visual identification of the RLN is the gold standard in thyroid surgery, and for more than 30 years, this method has been complemented by the use of IONM of RLN and EBSLN during the procedure. The advantage of laryngeal nerve neuromonitoring over visual assessment alone is the ability to assess not only the preserved anatomical integrity of the nerve but also its function during surgery [5–8].

Today, the most common system for IONM is the use of an endotracheal tube with built-in surface electrodes. During patient intubation, the tube is precisely placed between the vocal folds. During thyroid surgery, the nerve is stimulated with a current of 0.5–2.0 mA using an electric probe (mono- or bipolar). After a latent period, a contraction of the vocal muscles occurs, which is recorded by surface electrodes placed on the intratracheal tube and transmitted to the receiving part – a neuromonitor, that displays the contraction as an electromyographic (EMG) wave. EMG wave amplitudes above 200 μV indicate the proper functioning of the nerve, and its absence at a current of 1–2 mA indicates the so-called signal loss and laryngeal nerve injury. A detailed knowledge of the LOS solution algorithm is important for the surgeon to correctly predict postoperative nerve function. This algorithm is described in detail in the recommendations for the use of neuromonitoring in thyroid surgery.

Cooperation with the anesthesiologist plays an important role in thyroid surgery using laryngeal nerve monitoring. It is important to correctly place the appropriately selected endotracheal tube so that the surface electrodes are adjacent to the vocal folds. To obtain a response from the vocal muscles during laryngeal nerve stimulation during intubation, short-acting muscle relaxants should be used [5].

During nerve stimulation, modern devices generate both an acoustic signal and an electromyographic signal (EMG wave) on the monitor. The EMG wave recording confirming the response of the laryngeal nerves should be archived and attached as a printout to the medical record.

During neuromonitoring surgery, the mapping technique is often used to identify the nerve in the surgical field by moving the stimulation probe at small regular intervals (1–2 mm) along the trachea [5]. The signal of the evoked potential in the nerve area directs the operator to its location and allows to determine its course correctly. The mapping technique is especially applicable during secondary procedures on the thyroid gland, where scar tissue has formed [20].

Laryngeal nerve monitoring is a standardized technique. This means that in all centers where this method is used, there is an accepted scheme of thyroid surgery using neuromonitoring, which includes examination of the larynx before and after surgery, as well as identification and assessment of the vagus nerve (V1) and laryngeal nerve (R1) activity both before and after removal of the thyroid lobe (V2 and R2, respectively) [5]. Examination of the larynx before surgical treatment allows to diagnose even subtle disorders of their functioning, which can often be asymptomatic. Besides, correct phonation does not always indicate the absence of disorders in the functioning of the vocal folds. Therefore, examination of the larynx after thyroid surgery is more important, as approximately 30% of vocal fold paralysis can occur with proper phonation. Vagus nerve stimulation prior to RLN detection is performed to verify the correct positioning of the endotracheal tube with built-in surface electrodes, which determines the optimal use of the neuromonitoring technique. Stimulation of the vagus nerve after thyroid resection is the most sensitive way to assess the function of the RLN and eliminates the possibility of its potential damage along its entire length (from the branching of the vagus nerve to the entrance to the larynx) [20].

Currently, we have different options for RLN monitoring: intermittent intraoperative neuromonitoring (I-IONM) using a handheld probe and continuous intraoperative neuromonitoring (C-IONM) using a temporary implanted vagus electrode [5; 7; 10; 20].

In 2020, the NIM Vital (Medtronic, Jacksonville, Florida, USA) was introduced to the market, offering NerveTrendTM EMG reports, which allows monitoring the condition of the nerves during the procedure, even if I-IONM is used [21].

In approximately 20% of cases, the EBSLN cannot be identified by imaging alone, as the nerve has a subfascial or intramuscular path in the lower constrictor muscle. Nerve stimulation can objectively identify the EBSLN, resulting in a visible twitch of the cricothyroid muscle in all (100%) cases. The use of IONM should not be limited to RLN but should also be expanded to mapping of EBSLNs, their identification and functional testing during thyroidectomy [11; 22].

Neuromonitoring allows for precise cutting of the laryngeal nerves from the surrounding tissues [5–7, 10; 11] and significantly increases the radicality of the operations performed. Barczynski et al. showed that the average 131I iodine uptake after total thyroidectomy using IONM compared to procedures without neuromonitoring was (0.67 ± 0.39)% versus (1.59 ± 0.69)% ($p < 0.001$), and the percentage of patients with iodine uptake below 1% increased by 45% when neuromonitoring was used [22].

Neuromonitoring allows predicting postoperative activity of the RLN during surgery, which virtually eliminates the risk of bilateral damage [5; 7; 11]. The introduction of neuromonitoring in thyroid surgery has given rise to the concept of two-stage thyroidectomy. It involves refraining from removing the second lobe of the thyroid gland if there is a suspicion of nerve damage on the side where the operation is already performed (the presence of signal loss on the side where the operation was performed). This procedure is intended to protect the patient from bilateral paresis of the thyroid gland and possible tracheostomy [23].

Since IONM has been introduced into thyroid surgery, there has been an ongoing debate about prevalence of IONM over imaging. In general, the effectiveness of identifying RLN using neuromonitoring is 98–100% and is statistically significantly higher than visual identification, which has been confirmed by numerous multicenter studies [5–7, 10; 11; 24; 25]. The achievements of the Odesa surgical school in thyroid surgery in general confirm these statements [26–29].

Conclusions. the introduction of intraoperative monitoring into surgical practice in the treatment of thyroid diseases prevents RLN and EBSLN injury, and improves the quality of life of patients.

BIBLIOGRAPHY

1. Nayyar SS, Thiagarajan S, Malik A, Chakraborthy A, Velayutham P, Chaukar D. Risk factors predisposing for recurrent laryngeal nerve palsy following thyroid malignancy surgery: experience from a tertiary oncology centre. *Eur Arch Otorhinolaryngol*. 2020; 277(4): 1199–1204. doi: 10.1007/s00405-020-05788-0. PMID: 31927640.
2. Padovano M, Scopetti M, Tomassi R, et al. Mapping complications in thyroid surgery: statistical data are useful for medico-legal management of a recurrent safety issue. *Updates Surg*. 2022; 74(5): 1725–1732. doi: 10.1007/s13304-022-01357-8. PMID: 36028654; PMCID: PMC9481495.
3. Gunn A, Oyekunle T, Stang M, Kazaure H, Scheri R. Recurrent Laryngeal Nerve Injury After Thyroid Surgery: An Analysis of 11.370 Patients. *J Surg Res*. 2020; 255: 42–49. doi: 10.1016/j.jss.2020.05.017. PMID: 32540579.
4. Dughiero S, Torresan F, Censi S, Mian C, Carrillo Lizarazo JL, Iacobone M. Risk and Protective Factors of Postoperative and Persistent Hypoparathyroidism after Total Thyroidectomy in a Series of 1965 Patients. *Cancers (Basel)*. 2024; 16(16): 2867. doi: 10.3390/cancers16162867. PMID: 39199638; PMCID: PMC11352404.
5. Deshmukh A, Thomas AE, Dhar H, et al. Seeing Is Not Believing: Intraoperative Nerve Monitoring (IONM) in the Thyroid Surgery. *Indian J Surg Oncol*. 2022; 13(1): 121–132. doi: 10.1007/s13193-021-01348-y. PMID: 35462673; PMCID: PMC8986933.
6. Aygun N, Kostek M, Isgor A, Uludag M. Anatomical, Functional, and Dynamic Evidences Obtained by Intraoperative Neuromonitoring Improving the Standards of Thyroidectomy. *Sisli Etfal Hastan Tip Bul*. 2021; 55(2): 146–155. doi: 10.14744/SEMB.2021.45548. PMID: 34349588; PMCID: PMC8298074.
7. Aygun N, Kostek M, Isgor A, Uludag M. Recent Developments of Intraoperative Neuromonitoring in Thyroidectomy. *Sisli Etfal Hastan Tip Bul*. 2021; 55(3): 273–285. doi: 10.14744/SEMB.2021.26675. PMID: 34712067; PMCID: PMC8526228.
8. Babu RD, Paul D. Laryngeal Nerves and Voice Change in Thyroid Surgery. *Indian J Surg Oncol*. 2022; 13(1): 99–108. doi: 10.1007/s13193-021-01318-4. PMID: 35462660; PMCID: PMC8986921.
9. Howick J, Cohen BA, McCulloch P, Thompson M, Skinner SA. Foundations for evidence-based intraoperative neurophysiological monitoring. *Clin Neurophysiol*. 2016; 127(1): 81–90. doi: 10.1016/j.clinph.2015.05.033. PMID: 26268581.
10. Chen B, Yang T, Wang W, Tang W, Xie J, Kang M. Application of Intraoperative Neuromonitoring (IONM) of the Recurrent Laryngeal Nerve during Esophagectomy: A Systematic Review and Meta-Analysis. *J Clin Med*. 2023; 12(2): 565. doi: 10.3390/jcm12020565. PMID: 36675495; PMCID: PMC9860817.
11. Cirocchi R, Arezzo A, D'Andrea V, et al. Intraoperative neuromonitoring versus visual nerve identification for prevention of recurrent laryngeal nerve injury in adults undergoing thyroid surgery. *Cochrane Database of Systematic Reviews*. 2019; 1(1): CD012483. DOI: 10.1002/14651858.CD012483.pub2.
12. Jeannon JP, Orabi AA, Bruch GA, Abdalsalam HA, Simo R. Diagnosis of recurrent laryngeal nerve palsy after thyroidectomy: a systematic review. *Int J Clin Pract*. 2009; 63: 624–629. doi: 10.1111/j.1742-1241.2008.01875.x.
13. Uludağ M, Tanal M, İşgör A. A Review of Methods for the Preservation of Laryngeal Nerves During Thyroidectomy. *Sisli Etfal Hastan Tip Bul*. 2018; 52(2): 79–91. doi: 10.14744/SEMB.2018.37928. PMID: 32595378; PMCID: PMC7315061.
14. Potenza AS, Araujo Filho VJF, Cernea CR. Injury of the external branch of the superior laryngeal nerve in thyroid surgery. *Gland Surg*. 2017; 6(5): 552–562. doi: 10.21037/gs.2017.06.15. PMID: 29142848; PMCID: PMC5676167.
15. Zhao Y, Zhao Z, Zhang D, Han Y, Dionigi G, Sun H. Improving classification of the external branch of the superior laryngeal nerve with neural monitoring: a research appraisal and narrative review. *Gland Surg*. 2021; 10(9): 2847–2860. doi: 10.21037/gs-21-518. PMID: 34733732; PMCID: PMC8514299.
16. Li C, Zhang J, Dionigi G, Sun H. Assessment of different classification systems for predicting the risk of superior laryngeal nerve injury during thyroid surgery: a prospective cohort study. *Front Endocrinol (Lausanne)*. 2023; 14: 1301838. doi: 10.3389/fendo.2023.1301838. PMID: 38075061; PMCID: PMC10703432.
17. Anand A, Metgudmath RB, Belaldavar BP, Virupaxi RD, Javali SB. Relative Topography of Laryngeal Nerves for Surgical Cruciality: An Observational Cadaveric Study. *Indian J Otolaryngol Head Neck Surg*. 2022; 74(Suppl 3): 4973–4977. doi: 10.1007/s12070-021-02537-5. PMID: 36742510; PMCID: PMC9895266.
18. Jin S, Sugitani I. Narrative review of management of thyroid surgery complications. *Gland Surg*. 2021; 10(3): 1135–1146. doi: 10.21037/gs-20-859. PMID: 33842257; PMCID: PMC8033047.
19. Sam TS, Cherian AJ, Chakravarthy NS, et al. Time to Revisit a Low-Cost Alternative? Palpation Assessment Nerve Monitoring (PANM) for Recurrent Laryngeal Nerve to Predict Postoperative Vocal Cord Function – a Validation Study Using an In-House Neuromonitoring Device. *Indian J Surg Oncol*. 2022; 13(1): 33–39. doi: 10.1007/s13193-020-01272-7. PMID: 35462675; PMCID: PMC8986893.
20. Ku D, Hui M, Cheung P, et al. Meta-analysis on continuous nerve monitoring in thyroidectomies. *Head Neck*. 2021; 43(12): 3966–3978. doi: 10.1002/hed.26828. PMID: 34342380.
21. Wojtczak B, Sutkowska-Stępień K, Głód M, Kaliszewski K, Sutkowski K, Barczyński M. Current Knowledge on the Use of Neuromonitoring in Thyroid Surgery. *Biomedicines*. 2024; 12(3): 675. doi: 10.3390/biomedicines12030675. PMID: 38540288; PMCID: PMC10968482.
22. Barczyński M, Konturek A. Clinical validation of NerveTrend versus conventional i-IONM mode of NIM Vital in prevention of recurrent laryngeal nerve events during bilateral thyroid surgery: A randomized controlled trial. *Head Neck*. 2024; 46(3): 492–502. doi: 10.1002/hed.27601. PMID: 38095022.
23. Christoforides C, Papandrikos I, Polyzois G, Roukounakis N, Dionigi G, Vamvakidis K. Two-stage thyroidectomy in the era of intraoperative neuromonitoring. *Gland Surg*. 2017; 6(5): 453–463. doi: 10.21037/gs.2017.07.15. PMID: 29142834; PMCID: PMC5676178.

24. Del Rio P, Cozzani F, Puteo N, Loderer T, Rossini M, Bonati E. IONM and thyroidectomy in benign thyroid disease. Analysis of adverse events. *G Chir.* 2019; 40(3): 174–181. Available from: https://journals.lww.com/jisa/Fulltext/2019/05000/IONM_and_thyroidectomy_in_benign_thyroid_disease_.3.aspx.
25. Dionigi G, Chiang FY, Hui S, et al. Continuous Intraoperative Neuromonitoring (C-IONM) Technique with the Automatic Periodic Stimulating (APS) Accessory for Conventional and Endoscopic Thyroid Surgery. *Surg Technol Int*. 2015; 26: 101–14. PMID: 26054997.
26. Grubnik VV, Parfentiev RS, Grubnik YV, Grubnyk VV. Intraoperative indocyanine green angiography for predicting postoperative hypoparathyroidism. *Surg Endosc*. 2023; 37(12): 9540–9545. doi: 10.1007/s00464-023-10466-3. PMID: 37721589.
27. Parfentiev R, Grubnik V, Grubnik V, Bugridze Z, Giuashvili S, Beselia L. Study of intraoperative indocyanine green angiography effectiveness for identification of parathyroid glands during total thyroidectomy. *Georgian Med News.* 2021; (314): 26–29. PMID: 34248023.Grubnik V., Parfentiev R., Kosovan V. Miniinv.
28. Grubnik V, Parfentiev R, Kosovan V. Miniinvazyvni videoasystovani vtruchannya na shhytopodibnij ta pryshhytopodibnyh zalozah. *Klinich. xirurhiya*. 2019; 86 (11/12): 42–45. https://doi.org/10.26779/2522-1396.2019.11-12.42 (in Ukrainian).
29. Grubnik VV, Parfentiev RS, Kresyun MS. Mozhlyvosti endoskopichnoho likuvannya vuzlovoho zobu. *Visnyk Vinnyc'koho nacional'noho medychnoho universytetu*. 2016; 20(1/2): 230–232. (in Ukrainian). Available from: https://www.vnmu.edu.ua/downloads/other/visnik_2016_20(1),%20Ch2.pdf.

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