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ELECTROPHYSIOLOGICAL IDENTIFICATION OF NERVES OF THE LARYNX AMONG THE TISSUES OF OPERATIVE WOUND IN GOITER SURGERIES

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Abstract

The objective of the study was to analyze the technology of electrophysiological identification of laryngeal nerves in goiter surgeries.
Methods: The technology of electrophysiological identification of laryngeal nerves in goiter surgeries was developed. It is based on the recording of changes in the sound vibrations generated by the passage of air through the voice gap, the area of which changes in the event of a change in the tension of vocal cords from electrostimulation of the laryngeal nerves. The greatest changes in the frequency and amplitude of sound vibrations occur when electrostimulation of tissues near the nerve and the nerve itself. This phenomenon allows to determine the location of the nerve and prevent its injury.
Results: The method was tested in 173 patients who had been operated for goiter. There were no cases of temporary or permanent disorders of phonation.

Résumé

L'identification électrophysiologique des nerfs laryngés parmi les tissus de la lésion opérée dans les opérations du goître

L'objectif de l'étude a été d'analyser la technologie d'identification électrophysiologique des nerfs laryngés lors des interventions chirurgicales du goître.
Méthodes: La technologie d'identification électrophysiologique des nerfs laryngés a été élaborée lors des interventions chirurgicales du goître. Elle est basée sur l'enregistrement des changements des vibrations sonores générées par le passage de l'air à travers la fente glottique, dont la surface se change en cas de changement de tension des cordes vocales à cause de l'électrostimulation des nerfs laryngés. Les changements les plus importants de la fréquence et de l'amplitude des vibrations sonores se produisent lors de l'électrostimulation des tissus près du nerf et du nerf lui-même. Ce

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Conclusions: The developed technology of electrophysiological identification of laryngeal nerves in goiter surgeries is reliable, easy to apply, and is not expensive. The influence of other factors on its results was not noted.

Key words: intraoperative trauma of laryngeal nerves, prevention, electrophysiological identification.

phénomène permet de déterminer la position du nerf et de prévenir son traumatisme.
Résultats: La méthode a été testée chez 173 patients qui ont été opérés pour un goître. Il n'y a eu aucun cas de troubles temporaires et permanents de la phonation.
Conclusion. La technologie élaborée d'identification électrophysiologique des nerfs laryngés lors des interventions chirurgicales du goître est fiable, façile à appliquer et pas chère. L'influence des facteurs extérieurs sur ses résultats n'a pas été constatée.

Mots clés: les traumatismes intra-opératoires des nerfs laryngés, la prévention, l'identification électrophysiologique.

Introduction

Intraoperative injuries of the laryngeal recurrent nerves are the most common and serious complications of goiter surgeries. Their frequency ranges from 0.3 to 2.5 % (according to some authors – up to 12 %) and has no tendency to decrease. The number of nerve injuries increases to 11–20 % in surgeries for recurrent goiter and cancer[1-3].

Over the past 10–15 years, there were papers devoted to neuro-monitoring of the outer branch of the upper laryngeal nerve[4-8].

The analysis of publications on neuronal monitoring of the larynx nerves suggests that the methods of electrostimulation and monitoring used today do not allow reducing the frequency of its damage. In other words, their use is not a priority and, in comparison with the gold standard – the visualization of the larynx nerves, does not reduce the frequency of parestheses of the larynx and postoperative disorders of its vocal function. They are useful only to verify if the nerve is intact or damaged. Therefore, there were opinions that raise the question of the feasibility of such monitoring. After all, it does not reduce the frequency of nerve injuries, significantly prolongues the duration of the operation, and the expensive equipment used unjustifiably increases the cost of surgery[8-10].

The objective of the study was to develop the technology of electrophysiological identification of the nerves of the larynx among the tissues of the operative wound.

Material and methods

The method was tested in 173 patients who had been operated for goiter. The technology of electrophysiological identification of laryngeal nerves in goiter surgeries was developed. It is based on the recording of changes in the sound vibrations generated by the passage of air through the voice gap, which changes in the event of a change in the tension of vocal cords from electrostimulation of the laryngeal nerves. The greatest changes in the frequency and amplitude of sound vibrations occur when electrostimulation of tissues near the nerve and the nerve itself. This phenomenon allows to determine the location of the nerve and prevent its injury.

Results and discussion

Motoneuron generates pulses with a frequency of 50–60 Hz and a duration of 60 ms[11]. At rest, its electrical potential is about 75 mV; when excited, one of the varieties of ions sharply passes to the opposite side of the membrane, creating a difference in potentials[12]. The motor neuron transmits electrical impulses with a frequency of 200–300 Hz, the optimal pulse duration for muscle activation ranges from 150 ms to 0.3 ms, and the membrane potential is from 130 to 190 mV[12]. Thus, the set of potentials of action and rest of the motor neuron can be described as an alternating current with different frequencies for different potentials. Taking into account these features of the physiology of motor neuron and the transfer of the nerve impulse from the nerve to the muscle, it should be noted that the use of pulsed current for nerve stimulation is non-physiological for the study of the activity of the nerve tissue[11].

The threshold of current sensitivity for motoneuron is different for women from 30 to 40 mA, for men – from 25 to 35 mA[12]. Thus, a current less than 25 mA will not cause the appearance of the action potential, and a current with a force exceeding 40 mA devastates the nerve tissue[11-12]. The

conductivity of the nerve depends on its thickness, that is, on the number of neurons forming the nerve. The motoneuron binds to adjacent neurons and muscles through synaptic compounds, the basis of which is the electrochemical reactions. One synapse conducts nerve impulses with a frequency up to 150 Hz, but the sumation of synaptic bonds of different axons allows several axons to transmit a signal to the muscle fiber with a maximum effective frequency of 400–500 Hz[11-12]. The difference in the potentials of synaptic membranes is about 75 mV, and the potential for muscle tissue in a resting state is from 100 to 150 mV, that is much higher than the potentials of activation of nerve fibers[13]. Due to greater resistance, the process of damping the electric impulse in muscle fibers passes much faster than in fibers of the nervous tissue. The frequency of oscillations should be of 350–450 Hz[11]. It is precisely the current with a frequency of 400 Hz that is optimal for conduction along the nerve tissue and synapses, between axons and muscle fibers, causing contractions with minimal effect on the refractoriness of the neuronal muscle system[13]. These circumstances determine the selective sensitivity of the nerve tissue to the action of the current with given parameters[12, 13].

Thus, by selecting certain parameters for the strength of the current, the electric power and the frequency of sinusoidal pulses for electrostimulation of tissues in the wound, one can clearly count on the received signal to be an answer to the irritation of the nerve. To stimulate the tissue of the surgical wound, we chose an alternating current with a frequency of 400 Hz and a voltage of 75 mV. Low sensitivity and conductivity are the features of the current electrostimulation, which are revealed in muscles and other injured tissues. The nerve tissue of the larynx are characterised by the high sensitivity and conductivity.

With spontaneous breathing, the passage of air through the vocal cavity creates sound vibrations, the frequency and amplitude of which depend on the tension of the vocal cords. Consequently, changes in their tension in response to nerve stimulation by electric current will be manifested by changes in the amplitude and frequency of sound vibrations. The registration of changes in these sound effects in response to electrostimulation of the tissues of an operating wound is based on our method of identification of the laryngeal nerves, or the determination of the place of passage of the laryngeal nerves among the tissues of the surgical wound.

To implement the electrophysiological identification of the laryngeal nerves, two conditions are needed. The first is the refusal to use muscle relaxants during anesthesia, as the relaxants block the transfer of impulses of action on the muscle in the synapses and make it impossible to identify the nerves among the tissues of the surgical wound by means of electrostimulation. That is, the operation is carried out with spontaneous breathing of the patient. The second condition is that the vocal cords should be free and intubation of the trachea is not carried out. Instead of the intubation tube, the laryngeal mask is used, as one of the important elements of the developed method. In addition, it prevents tongue-swallowing in spontaneous breathing and, if necessary, allows for inhalation support.

To identify the nerve larynx, we developed the device[14]. It consists of: an alternator, an audio signal sensor (microphone), an electric signal transformer unit, a unit for processing information and its display (Figure 1).

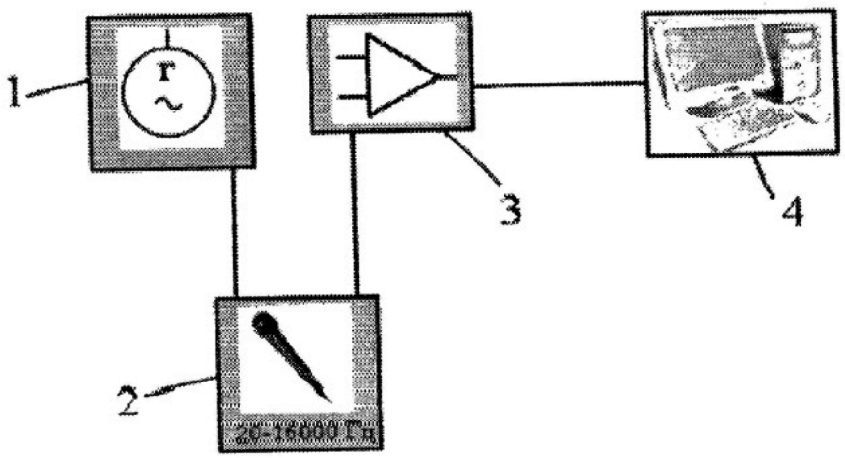

Figure 1. Block diagram of the device for the identification of the nerves of the larynx: 1 – alternator; 2 – sensor of sound signals (microphone); 3 – block of transformation of electric signals; 4 – block of processing of information and its display.

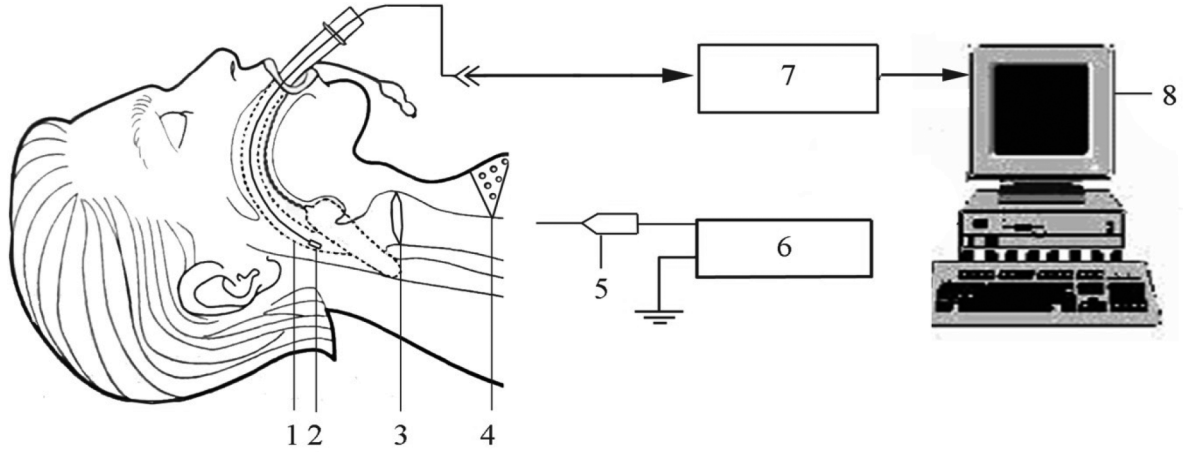

Figure 2. Technological scheme of identification of laryngeal nerves: 1 – laryngeal mask; 2 – sensor of sound signals; 3 – voice communication; 4 – surgical wound; 5 – electrode for irritation of wound tissues; 6 – alternator; 7 – filter and converter of sound signals; 8 – computer.

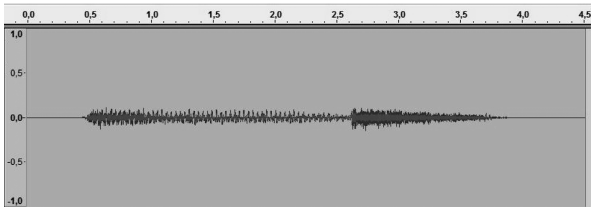

Figure 3. Record of background base signal without electrostimulation of the nerve.

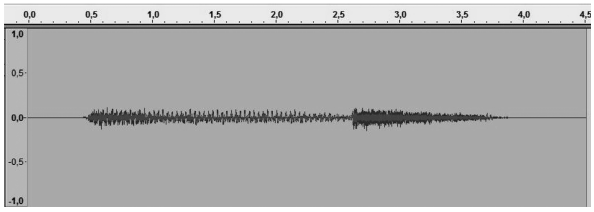

Figure 4. Signal at electrostimulation of wound tissues at a distance of 4–6 mm from the nerve.

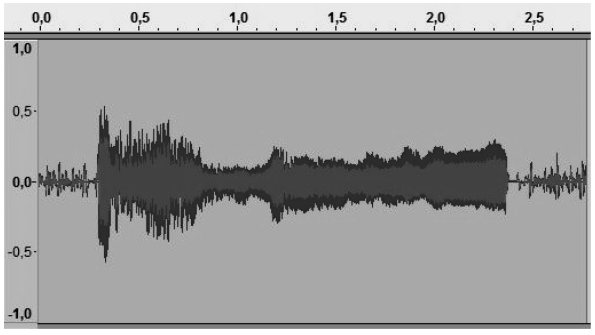

Figure 5. Signal at electrostimulation of wound tissues at a distance of 2–3 mm from the nerve.

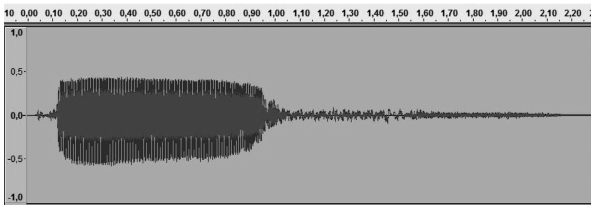

Figure 6. Signal during electrostimulation of the nerve.

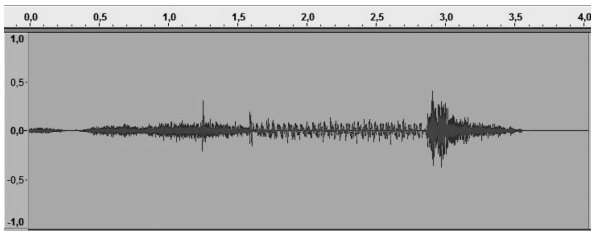

Figure 7. Fig. 7. Signal at electrostimulation of the upper nerve larynx.

The technology of laryngeal nerve identification is as follows. The passive electrode is injected into a deltoid muscle from either side. When manipulating the nerve passages, the larynx conducts electrophysiological identification among the tissues of the surgical wound of the corresponding nerve, according to the section of manipulations of the surgeon. For this, the surgeon with an active electrode touches the tissue of the wound in the areas of the expected passage of the nerve (Figure 2). On the PC screen, information about the result of electrostimulation is displayed.

Such information may be of different types and reflects either spontaneous breathing or the reaction of the nerve and muscles to irritation of tissues around the nerve at different distances or the nerve itself (Figures 3–7).

The closer to the nerve is the electrical irritation, the greater the amplitude of sound vibrations. At the same time, their frequency also changes.

It is not always possible to identify the nerve by the developed method in the event of a pronounced

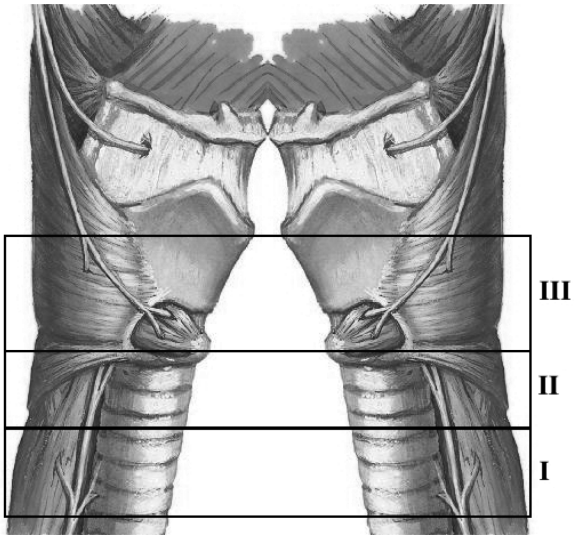

Figure 8 (author's drawing, dissertation Shidlovsky OV, 2012). Areas of the study on the identification of the nerves of the larynx: I – the lower poles of the thyroid gland; II – entry of the turning nerve into the larynx; III – the upper poles of the thyroid gland, the outer branch of the upper laryngeal nerve.

union process in surgeries for post-operative relapsing goiter or a widespread malignant process or multi-node goiter of large size, when there is a technical difficulty in performing the operation. Thus, we restrict ourselves to determine the area of its passage or location, which during the operation should be especially controlled and, if necessary, bypassed to prevent the injury of the nerve. The area of the passage of the nerve is determined by the highest intensity of the response signals to the electrical inflammation of the tissues of the surgical wound.

Nerves were identified in strictly selected areas, that is, in those where the most likely trauma of the laryngeal nerves is possible. This is the area of the lower pole of the glandular particles (I), the Beri's ligament zone and the occurrence of the nerve in the larynx (II) and the region of the upper pole of the glandular particles (III), in particular the outer branch of the upper laryngeal nerve (Figure 8).

The results of the research on the identification of laryngeal nerves among the tissues of the surgical wound are presented in Table 1.

The developed technology allowed, in critical situations, establishing areas for the passage of turning nerve and to protect them from injuries, and patients – from paresis of larynx and phonation disorders.

In the early and remote postoperative periods, we didn't find any permanent or transient paresis of the larynx in patients. In the early postoperative period, in some patients, voice disorders (voice changes) were due to trauma and larynx trauma as a result of surgery.

Based on the results of research carried out on the development and introduction of laryngeal nerve identification technology in the clinical practice, it was concluded that the method and technology of its implementation allow to unambiguously identify intraoperatively both the recurrent and superior nerves of the larynx. Particular mention should be made on the possibility of identification of the superior nerves of the larynx.

Conclusions

Technical support of the method is not expensive. The technique of intraoperative identification of the laryngeal nerves is simple. The influence of external factors and conditions on the results of the study was not noted. The method does not take much time, it takes a total of 7–12 minutes. Investigations are carried out with the participation of a technician-operator, who by the corresponding computer programs fixes the received data. There are no contraindications to use the method.

Conflicts of interest: The authors declared no conflict of interest.

Table 1. Identification of laryngeal nerves in operated patients

Diseases of the thyroid gland	*Recurrent nerves*		*Superior nerves*	
	identified	*unidentified*	*identified*	*unidentified*
Nodular unilateral goiter (n=29)	33 (100 %)	–	33 (100 %)	–
Nodular bilateral goiter (n=41)	76 (93 %)	6 (7 %)	78 (95 %)	4 (5 %)
Thyroid cancer (n=12)	19 (79 %)	5 (21 %)	23 (96 %)	1 (4 %)
Mixed toxic goiter (n=13)	23 (88 %)	3 (12 %)	25 (96 %)	1 (4 %)
Diffuse toxic goiter (n=8)	15 (94 %)	1 (6 %)	13 (81 %)	3 (19 %)
Recurrent goiter (n=6)	7 (70 %)	3 (30 %)	9 (90 %)	1 (10 %)
Total	173 (90 %)	18 (10 %)	181 (95 %)	10 (5 %)

Note. Unidentified cases are cases where the nerves are not allocated, but with the help of the method, the place of their passage is clearly defined.

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