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ENGINEERING SCIENCES

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INTELLIGENT TECHNOLOGIES OF FUNCTIONAL DIAGNOSIS AND MODELING OF SURGERY OPERATIONS

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ABSTRACT

Thus, the authors proposed intellectual technologies for modeling and computer planning of surgical interventions on the basis of complex processing and analysis of diagnostic data implemented in rhinolaryngology, otology, ophthalmology, neurosurgery, plastic and vascular surgery. Development has a pronounced complex socio-economic effect, which is achieved by a direct decrease in the cost of the proposed remedies in comparison with known counterparts, taking into account the reduction of the cost of staying in the hospital and payment of sick leave, reducing relapses and reducing the loss of production due to illness of the worker by reducing the time spent on stationary treatment.

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Introduction. The progress of modern medicine is largely due to the wide introduction and use of advanced achievement in information technology and instrumentation. Today, in all industrialized countries of the world, one of the most urgent social problems are the development and introduction of new medical technologies to improve the quality of medical care provision. Increasing the effectiveness of health care delivery standards are one of the most urgent social challenges in all developed countries, as evidenced by the EU Horizon 2020 / H2020 EU Program for Research and Innovation, which is being actively implemented during 2014-2020. One of the priorities of this program is "Social Challenges" with the theme "Health, demographic changes and welfare" aimed at improving the health and well-being of European citizens throughout their lives.

Therefore, the use of scientific, technical and production potential for the improvement and development of innovative methods and medical devices are a strategically important task for the field of Ukrainian biomedical engineering and the development of information technologies in the formation and support of diagnostic decisions [1-3].

Modern medical diagnostics are based on the evidence-based approach, which is based on the use of high-precision equipment and new information technologies for obtaining reliable quantitative

data on the state of the human body. At present, the most active evolution is observed in the functional diagnostic methods, which are aimed at the registration of quantitative indicators of the physiological functions of any organ, or the entire organism and the detection of violations, depending on the specific pathology. This information is especially useful for practicing clinicians, since it allows you to link the anatomic-morphological and physiological parameters of the investigated organ to clarify the picture of the pathological process. Functional researches are also actively used in sports medicine, in professional selection and preventive examinations to determine physical abilities of a person.

But the simple increases in the accuracy of measurements of physiological indicators do not allow forming and justifying a clear correlation between subjective sensations of a patient and diagnostic data. Therefore, only modern intelligent technologies support decision's can increase the reliability of the results of diagnostic studies using specialized data processing methods and providing the clinician with additional, extended information about the pathological process.

However, the methods and hardware of functional research and medical imaging have mainly been refined with an emphasis on conducting exclusively diagnostic procedures and, as their logical development, in the last decade began to develop the direction of computer simulation and planning of surgical interventions. The problem of development of intelligent technologies for modeling surgical interventions, taking into account the capabilities of modern diagnostic and surgical equipment, was considered rather isolated, narrowly are specialized, without the use of a systematic approach. At the same time, the lack of theoretical foundations and clear principles of modern intellectual technologies for the simulation of surgical interventions significantly limits the possibility of increasing the efficiency of surgical treatment methods and complicates the transition of surgical procedures to modern standards and criteria of evidence-based medicine [4-5].

The complexity of planning methods for surgical interventions at the present stage are dictated, first of all, by the complexity of the diagnostic and therapeutic tasks faced by a specialist in a large number of technical means and the receipt of heterogeneous information in this structure. In this case, special attention should be paid to the development of instrumental methods of functional diagnosis, according to objective data, which are implemented procedures for planning of surgical intervention.

But nowadays despite the development of technical means in functional diagnostics, the problem of data repeatability during the measurement of physiological parameters of the human body in the absence of a standard remains actual topical issue. Such methods at the present stage require the introduction of clear and demonstrable criteria necessary for making informed diagnostic decisions, forecasting and determining the effectiveness of functional operational interventions at the evidence level, which are only possible through the application of intelligent processing and analysis technologies.

Therefore, the purpose of the work is to create of intelligent technologies for functional diagnostics and simulation of surgical interventions based on methods of instrumental evidence-based diagnostics, virtual modeling and prediction of the results of surgical interventions.

Results of the study. The development is based on the years of experience of domestic specialists in the field of medical instrumentation and information technology, cooperation with leading medical centers and foreign institutions, which has enabled the creation of an excellent biotechnical complex that uses modern technical solutions, complex biophysical models, intellectual technologies and structural forms for increasing the validity of the results of diagnosis and effectiveness of holding surgical treatment.

Domestic and direct analogues in the world of the proposed complex are not present, and the number of significant foreign publications confirms that this is the first system development in the field of biomedical engineering for virtual simulation and computer planning of surgical interventions based on intelligent data processing and data analysis [6-8].

The scientific part of the work is that.

– for the first time the theoretical bases and conception of creation of intellectual technologies of functional diagnostics and designs of surgical interferences, that are based on the decision of configuration and trajectory tasks and association functional and anatomic diagnostic data, that allows the development of modern automated biotechnical complexes of evidence-based instrumental diagnostics and surgical treatment are developed;

– the concept of developing diagnostic process for nasal breathing testing has been further developed, which, due to the application of the method of dynamic back active rhinomatometry with forced breathing and intelligent data processing technologies, provides assessment of the aerodynamic resistance of the upper respiratory tract with maximum physiological measurements procedures taking into account individual variability;

– for the first time on the basis of the intellectual analysis of indicators of nasal aerodynamics on a microlevel the theoretical ground of mechanism of injuring of mucous membrane of nasal cavity is conducted by the current of air flow has been carried out, which is based on the definition and comparison of the corresponding values of the thickness of the laminar membrane airflow and roughness of the mucous membrane, which allow to increase the adequacy of the methods of diagnosis and surgical treatment. pathologies associated with nasal breathing disorders;

– for the first time, a method of computer simulation and configuration planning of rhinoconstrictive interventions were developed on a comprehensive aerodynamic model of the upper respiratory tract, based on the combination of anatomical data of computer tomography and functional results of rhinomatometry, which allow, on the basis of virtual modeling, corrective surgical interventions for data of a deforming warping mathematical model to predict the functional results of the operation depending on the modes of breathing and the individual physiological variability [5].

– for the first time, the concept of the formation of a minimally traumatic trajectory of neurosurgical access has been developed, which is based on the intellectual technology of constructing a map of indexes of risk of damage to anatomical and functional structures of the brain, which allows to increase the efficiency of neuronavigation and reduce the risk of postoperative complications.

– the method of modeling of corrective ophthalmic interventions in the treatment of strabismus is

– proposed, which is based on the three-dimensional model of the oculomotor apparatus and the introduction of the geometric properties of the eyeball in the ophthalmic spherical coordinate system and allows to take into account the indices of individual anatomical variability in computer planning of surgical interventions.

– the method of modeling of corrective ophthalmic interventions in the treatment of strabismus is proposed, which is based on the three-dimensional model of the oculomotor apparatus and the introduction of the geometric properties of the eyeball in the ophthalmic spherical coordinate system and allows to take into account the indices of individual anatomical variability in computer planning of surgical interventions.

– the method of diagnosing arterial pathologies of the human blood circulation system is improved, which differs from the existing one by the fact that using expert knowledge bases concerning the basic hemodynamic parameters allows to concretize the degree of severity of the disease and obtain predictive parameters taking into account individual variability at the evidence level;

– the theory and methods of constructing audiometry and acoustic impedancometry methods have been developed, which allowed, on the basis of the obtained analytical expressions of the measurement and reproduction equations, to determine the ways of increasing their accuracy, and also to expand the functionality due to the implementation of the method of HF audiometry not only in air, but bone conduction of sounds, taking into account the age and sex of the subjects under the formation of a conclusion on the state of their hearing, automation of the procedure of research, implementation of additional modes of the environment TION and integration methods audiometry and acoustic impedancemetry one vehicle.

The practical significance of the work is that:

– implemented intellectual technologies in diagnostic devices with advanced functional capabilities; appropriate methodological recommendations for instrumental diagnostics and computer planning of surgical interventions have been developed, which in the long run will solve the problem of equipping medical centers with high-quality and inexpensive domestic equipment;

– the methods of attestation, calibration and preliminary clinical approbation of diagnostic devices have been developed, as well as the basic medical and technical requirements and practical recommendations for designing biotechnical complexes of virtual simulation and computer planning of surgical interventions in various fields of medicine [9-10];

– advanced understanding of the physiology of the upper respiratory tract due to the developed mathematical models and intelligent data processing technologies, which allows receiving support for the adoption of diagnostic solutions taking into account individual variability;

– the results of the work have been implemented in production, in the creation of perspective plans for the manufacture of medical equipment, in various clinical institutions of Ukraine and in the teaching of disciplines in several universities of Ukraine.

Joint research with Kharkiv National Medical University, Ukrainian Medical Stomatological Academy (Poltava), National Technical University of Ukraine "Kyiv Polytechnic Institute", Vinnytsya

National Technical University, CM Clinical Hospital and MK "Kharkiv Regional Clinical Hospital" have been fulfilled.

Brief contents of the work. Based on practical experience, the concept is proposed based on the intellectual technologies of functional diagnostics, virtual modeling and computer planning of surgical interventions in otorhinolaryngology, ophthalmology, neurosurgery, plastic surgery and vascular surgery, which is based on the principles of trajectory and configuration virtual simulation of surgical interventions. The principle of configuration virtual simulation of surgical interventions is based on the study of a complex morpho-functional model of the anatomical region and the prediction of functional treatment results by modifying the geometric properties of anatomical structures (fig.1). The principle of trajectory virtual simulation of surgical interventions is based on solving the problem of determining the optimal (according to the criterion of least traumatism) surgical access to a definite anatomical region [11-12].

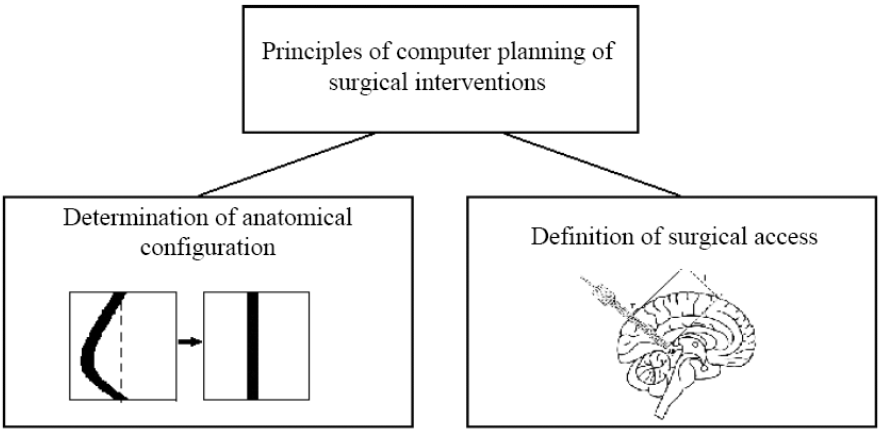

Fig. 1. Classification of the principles of computer planning

The biotechnical complex of computer planning of surgical interventions, which includes systems of introscopic diagnostics, which allows to carry out the anatomical mapping of the structures subject to operational intervention, the system of functional diagnostics, which allows to obtain data on the functioning of the investigated structures, systems of computer planning of surgical interventions, in which the formation of initial parameters for surgical equipment is carried out on the basis of virtual simulation forecasting anatomical and functional results of surgery [3-4].

The authors suggested that the system of computer planning of surgical interventions includes a module for constructing a complex anatomical and functional model, which is formed according to the data of an introscopic examination and the results of functional diagnostics, modules of virtual simulation of surgical interventions, prediction of results and formation the source data for the management of surgical equipment, and an independent module, for example, a cytological, verification of the results. In the visualization and rapid prototyping module, the results of the work are displayed at all stages of the system's operation and the possible production of full-scale 3D models for visual phantom simulation of surgical interventions.

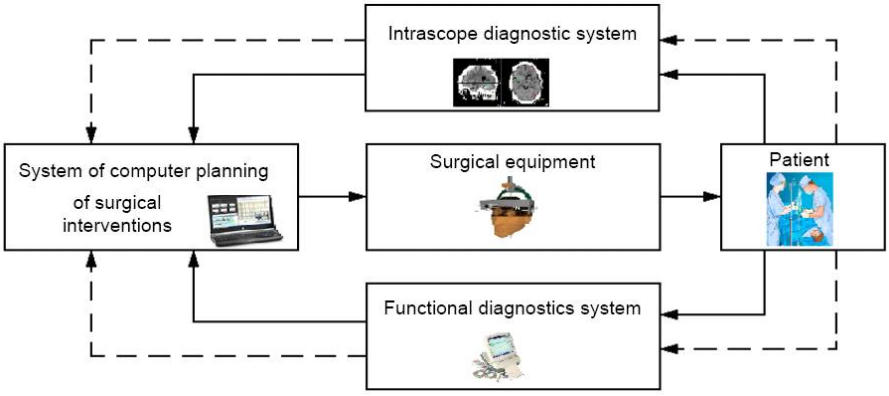

Fig. 2. Biotechnical complex of instrumental diagnostics and computer planning of surgical interventions

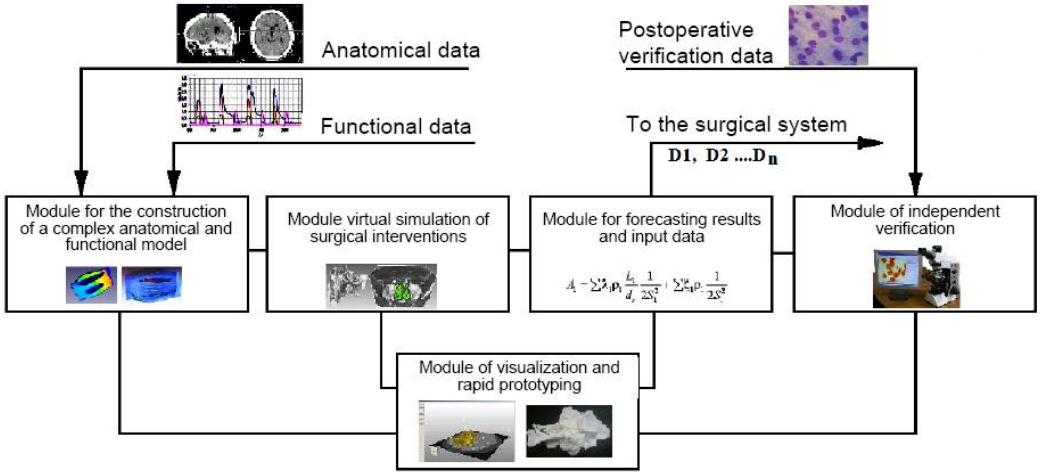

Fig. 3. The system of computer planning of surgical interventions, the work of which is illustrated by the example of functional rhinosurgery

Thus, the authors proposed intellectual technologies for modeling and computer planning of surgical interventions on the basis of complex processing and analysis of diagnostic data implemented in rhinolaryngology, otology, ophthalmology, neurosurgery, plastic and vascular surgery.

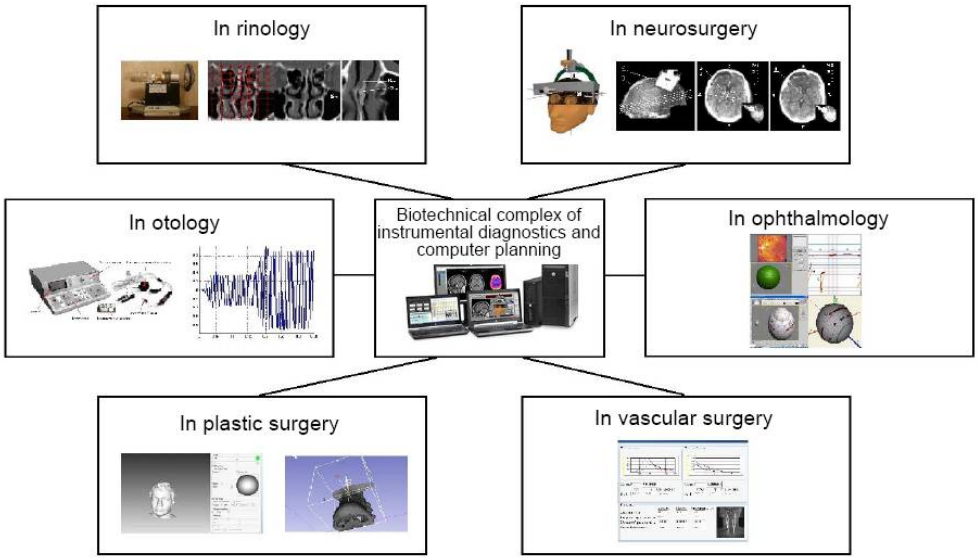

Fig. 4. Areas of application of the proposed intellectual technologies by the authors, where practical application has already been obtained

Development has a pronounced complex socio-economic effect, which is achieved by a direct decrease in the cost of the proposed remedies in comparison with known counterparts, taking into account the reduction of the cost of staying in the hospital and payment of sick leave, reducing relapses and reducing the loss of production due to illness of the worker by reducing the time spent on stationary treatment.

The work consistently solves the problems of creating intelligent technologies of objective instrumental diagnostics and computer planning of surgical operations in various fields of medicine that require high-precision modern equipment. This allows specialists from different fields to get acquainted with the proposed developments and prepare for their use in practical activities. The future improvement of computer simulation of surgical interventions is to find opportunities for further formalization of the methods of modeling of medical influences, the development of mathematical models and methods for forecasting and assessing the effect of the degree of correction of anatomical and functional structures on physiological parameters.

It is established that in the trajectory principle, in order to provide the optimal criterion for the least invasive surgical access, it is necessary to introduce the function of the integral invasiveness of the trajectory of the surgical instrument, which is based on the use of indices of invasiveness of the anatomical and functional structures of the brain, depending on the level of the danger of damage. The use of the power integral invasive function allows ranking of possible trajectories of surgical access without the effect of accumulation overlap in the total number of invasive indexes, which provides exhaustive mapping of the skull and structures of the brain in terms of the risk of operational damage and allows the creation of a database of operational access with intelligent decision support technology in consideration individual anatomical variability [8].

At the configurational principle there is a need to combine the findings of aerodynamic modeling with the data of computer tomography and the results of rhinomatometric diagnostics for adequate interpretation and independent verification of nasal breathing test methods.

Methods for determining the aerodynamic characteristics of the nasal cavity on the basis of intelligent processing of computer tomography data allow for virtual simulation of correction of endonazal structures, which makes them more promising in relation to standard rhinomatometry, due to the possibility of using their prognostic results in computer planning of functional rhinorhirurgic interventions. Moreover, the combination of a modern elemental base with new information technologies and methods of intelligent data analysis allows us to discover new patterns regarding physiological processes and, for example, to study the influence of air flow on the nasal cavity mucous membrane at the micro level and to identify mechanisms for the development of chronic upper respiratory diseases, which associated with respiratory disorders.

The methods of metrological attestation, calibration and operation of the original nasal breathing test device are developed, which allows to create practical recommendations for conducting rhinomatometric diagnostics, which is related to the correct placement of measuring and auxiliary devices, processing and analysis of data, which can prevent gross errors in interpretation. results when testing nasal breathing [7].

It has been established that in modeling of surgical intervention on human facial tissue on the basis of the developed method of moving related volume elements, in order to preserve the spatial configuration of anatomical structures, the voxel density of the virtual model should be not less than 5000 elements per cubic centimeter, but for computer the functional rhinoconjugation modeling is not less than 7,000 voxels per cubic centimeter of tissue, due to the accuracy of constructing a geometric model for the further determination of aerodynum ary air flow characteristics.

Conclusions. The metrological methodical and hardware support for audiometrers and mid-ear analyzers with advanced functional capabilities has been developed, improved and experimentally tested, and this is the basis for further work on creation and improvement of the metrological support system in the field of high-frequency audiometry and acoustic impedancometry in Ukraine. These tools provide an opportunity to solve the problem of early diagnosis and prevention of hearing impairment in different groups of the population.

The method of computer modeling of ophthalmic interventions is developed, which, based on the calculation of the moments of the forces of the oculomotor muscles on the surface of the model of the eyeball, allows to determine the resulting moment of the forces of the whole complex of eye muscles and to predict the consequences of surgical intervention.

Software tools for trajectory computer programming and experimental model of hardware and software for surgical navigation are developed. The basic medical and technical requirements for a computer planning system and practical recommendations for its operation are determined.

The work highlights many years of experience gained by the authors in collaboration with prominent scientists, research and technological institutes of Ukraine, in international collaboration with the Institute of Multiphase Processes of the University. V. Leibniz (Hanover, Germany) as part of BMBF, DAAD,

Erasmus + projects.

On the subject of work published 324 scientific works, of which:

- monographs - 25;
- study aids - 2
- Patents and Inventions - 33;
- articles in scientific journals - 193, of which published in foreign publications - 57;
- abstracts at scientific conferences - 69;
- Theses for obtaining the degree of Doctor of Technical Sciences - 3;

- Theses for obtaining the degree of a candidate of technical Sciences - 29;
- Theses for obtaining the degree of a candidate of medical sciences - 1;
- h-index for work in Scopus - 10, h-index for work in Google Scholar – 14

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