The Concept of a Decision Support System in the Management of Treatment and Accompaniment of the Patient with Bronchopulmonary Diseases

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Abstract. The article describes the development of the concept of Decision Support System (DSS) in the management of treatment and accompaniment of patients with bronchopulmonary diseases. The main purpose of DSS is to improve the efficiency of processing and use of medical data for the transition to personalized medicine and high-tech health care using advanced information technology methods on the example of respiratory diseases. The proposed concept of DSS in the treatment and accompaniment of patients with bronchopulmonary diseases differs by the integration in the implemented modules of the system of semantic analysis of semi-structured data of clinical guidelines and case histories of patients; methods of automated recognition of specific functional diagnostic data of patients; knowledge base of the system based on ontological approach for semantic description of the poorly formalized subject area of bronchopulmonary diseases treatment; multi-agent technology in modeling the interaction between a doctor and a patient to form a personalized approach to the trajectory of diagnosis and treatment. The results of analysis of opportunities of artificial intelligence tools for decision support in the process of treatment and accompanying the patient are presented. The mathematical statement of the problem of management of the process of treatment and accompaniment of a patient with bronchopulmonary diseases is formulated. The scheme of decision support in the management of treatment and accompaniment of a patient with bronchopulmonary diseases was developed. At the stage of information system design, system models in IDEF notation were developed for realization of decision support in management of treatment and accompaniment of patient, which serves as a basis for software development of the proposed DSS. #CSOC1120.

Keywords: decision support system · treatment and accompaniment of the patient · artificial intelligence technologies · bronchopulmonary diseases

1 Introduction

Today there are systems created using computer technology to help the doctor make a decision based on the available symptoms and analyzes - decision support systems (DSS). They are based on methods of data analysis and artificial intelligence in the

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diagnosis, treatment and maintenance of a patient with bronchopulmonary diseases and more. Such systems make it possible to facilitate the work of employees of medical organizations, reduce the likelihood of an incorrect diagnosis and increase the efficiency of the process of providing medical services.

The main purpose of DSS is to increase the efficiency of processing and using medical data for the transition to personalized medicine and high-tech healthcare using advanced information technology methods. This will be presented on the example of respiratory diseases, which were chosen as the object of study due to their high socio-economic significance, the active development of the fundamental research base of pulmonology and the developed structure of international and national clinical guidelines.

The emergence of new intelligent technologies necessitates the development of the DSS concept. This will allow to achieve more effective interaction between the doctor and the patient, to form a better trajectory for the disease diagnosis and treatment, to interactively assess the quality of life of the patient, and also to generate recommendations and monitor the dynamics of the patient's condition using knowledge bases and semantic analysis technologies.

This article proposes the concept of a decision support system for managing the treatment and accompaniment of the patient with bronchopulmonary diseases based on the use of special technologies for processing semi-structured and poorly formalized data. Int the first chapter there is a problem description and the problem statement. The second chapter discusses known approaches to the organization of DSS in medicine. The third chapter of the article outlines the proposed approach to the development of DSS in the treatment and maintenance of patients. The fourth chapter provides a mathematical formulation of the managing problem of the process of treatment and accompanying patients. The fifth chapter shows the development of system models of DSS using the IDEF notation. The sixth chapter discusses the results of the implementation of the proposed approach.

2 Problem Description and Problem Statement

The development of a concept for building intelligent decision support systems for diagnosing, treating and accompanying a patient using data analysis technologies and artificial intelligence methods is necessary to improve the efficiency of medical data processing, reduce the risk of medical error and improve the patient's quality of life in order to implement the transition to personalized medicine and high-tech healthcare. A feature of the subject area of bronchopulmonary diseases is the specificity of the analysis of semi-structured data necessary to support decision-making in the diagnosis and treatment. X-ray images, case histories, disease symptoms, clinical recommendations presented in a descriptive form require the use of special technologies for processing semi-structured and poorly formalized data, such as ontological modeling and sematic data analysis.

The main objective of the study is to develop a DSS concept based on data analysis methods and artificial intelligence in the diagnosis, treatment and support of a patient with bronchopulmonary diseases, which will allow organizing effective interaction between a doctor and a patient.

3 Known Approaches to the Organization of Decision Support in Medicine

The issues of development, research and implementation of decision support systems in medicine, and in its various aspects, are raised in the following works:

The authors [1–4] claim that modern medicine is mastering decision support systems (DSS) by analyzing Russian and foreign sources. Work is underway to identify the main obstacles to the creation of DSS for medicine. Possible approaches to overcome conceptual barriers are also presented and the possibility of a comprehensive solution to the problem is proposed. The author considers a hybrid model of a wide class DSS for medicine. According to the author, the results of his work can be used by IT developers to build a DSS based on the scientific and empirical components of medical knowledge.

In the next article [5], the author considers the intellectual support of a doctor at the stage of making diagnostic and therapeutic decisions to reduce the likelihood of errors. The author explains the relevance of the chosen topic by the need to improve the procedures for supporting decision-making by a doctor at the stage of making a preliminary diagnosis. As a method for solving this problem, a model based on association rules was chosen, which is the basis of the mathematical software for the decision support system and allows a conclusion about a preliminary diagnosis with a high degree of certainty.

In the article [6], the author substantiates the prospects of creating decision support systems (DSS) in medicine and analyzes the feasibility of mass implementation of DSS, the principle of their operation based on a medical-digital system for human capital management, and also gives examples of clinical DSS in Russia and abroad based on 4-P medicine.

In the article [7], the author believes that recently a large number of intelligent systems have begun to appear that are used to support medical decision-making - "artificial intelligence in medicine". The author comes to the conclusion that in some cases the demonstration of the successful operation of the software in the declared characteristics (sensitivity, specificity) occurs only in the "good hands" of developers on the data that underlie the software. But when demonstrating work in clinical situations, the claimed performance is often not achieved, so the opinion of the clinical community, which should use this AI-based solution, is not always favorable. The author considers various types of errors that can be fatal in making medical clinical decisions. Thus, when developing AI-based solutions, it seems important to take into account the previously mentioned aspects for both developers and users.

The article [8] discusses the application of software and information solutions that form a comfortable working environment for the doctor. According to the author, due to the great complexity and insufficient knowledge of diseases, the large amount of constantly updated knowledge, and often limited resources, it is extremely important to help in making decisions using modern computer technologies. The author believes that digital clinical decision support systems can improve the diagnosis and treatment of diseases, reduce the frequency of erroneous and suboptimal decisions, and help individualize therapeutic programs. The article also states that the use of a clinical decision support system is most effective when implemented as a program for mobile devices: this allows the doctor to use tools anywhere and at any time.

The author in the article [9] considers the actual tasks of healthcare informatization, reveals the role of information technologies in the development of preventive medicine and medical decision support systems. The author believes that information technology in combination with the latest technology will play an important role in the development of preventive medicine, and one of the first places should be given to preventive monitoring systems and decision support systems. Also, according to the author, the healthcare informatization projects of the Russian Federation should include priority areas related to the development and implementation of medical decision support systems as part of automated workstations (AWS) of medical personnel. And the basis of such developments can be modern technologies of data mining.

In the article [10], the author, using a large-scale sample of American hospitals located in different medical regions, empirically investigates how the implementation of CDSS by the hospital and neighboring hospitals affects the quality of medical care. The author found that the introduction of CDSS significantly reduces the recurrence rate of patients in the hospital with heart failure, acute myocardial infarction and pneumonia. A regional side effect of implementation has also been identified, where the implementation of CDSS by neighboring hospitals in the same medical region also reduces hospital relapse rates. Such side effects become more significant with electronic data interchange, facilitating smooth and error-free communication between hospitals. The results presented by the author offer theoretical and managerial insights for health care researchers and practitioners.

In [11], the author presents a model of a decision support system in medicine when making a diagnosis. As a knowledge base of the expert system, a table of values based on the concepts of "absence / presence" of symptoms is presented. Further, the method of searching for the most probable disease with a custom vector specified in the body of the function was programmatically implemented. In the work, an approach was considered and tested in the case of incompleteness of the input data and the complication of the knowledge base, by introducing a symptom weight coefficient in the symptom complex of diseases.

In the article [12], the author says that CDSS can be classified into information-reference and intelligent systems. The latter can be divided into modeling and simulating reasoning systems. Modeling systems are based on formalized knowledge of experts, and simulating systems are based on models built by various methods of multivariate data analysis, including machine learning methods. Based on this, CDSS should be considered as a medical technology. Therefore, after their development, the following stages should follow: assessment of their analytical (technical) validity and clinical validation, during which evidence of the effectiveness of such systems in improving patient outcomes and their safety should be obtained, according to the author. Only after obtaining such evidence can a clinical and economic analysis be carried out in order to substantiate the economic feasibility of using CDSS.

In the article [13], the author conducted a brief review of the existing CDSS and showed the relevance of their application for solving the complex problem of choosing the optimal medical equipment. The author showed that the choice of the optimal model of medical equipment will ensure rational technical equipment and re-equipment of

healthcare institutions, which, according to the author, will ultimately lead to significant cost savings and an increase in the efficiency of the use of medical equipment.

The article [14] proposes a multi-stage algorithmic process for creating a CDSS based on a systematic approach. The author built a model for the development of a medical CDSS in the form of an IDEF0 diagram, a structural model of CDSS in relation to identifying the severity of a patient's condition, and a model for the medical decision-making process in the form of a cycle consisting of sequential procedures. The author proposes the integration of statistical packages and databases to create CDSS.

In the article [15], the author outlines the features, issues of application and prospects for the development of decision support systems in clinical practice and in the educational process. He also considers the specific characteristics of the clinical problem area that require consideration. In particular, attention was drawn to the effect of self-learning inherent in knowledge-based systems. The author presented the approaches and systems used in the educational process, including: "critical" systems, intelligent simulators and learning environments, including those that operate remotely.

Works in the field of application of information technologies (including intellectual ones) for processing medical data are actively carried out in various countries in various areas. However, the methodological basis for the formation of intelligent decision support in the diagnosis, treatment and further support of the patient, which combines a variety of intelligent technologies in a single methodology, has not been developed enough yet. Therefore, this problem is fundamental, and its solution is relevant, scientifically and practically significant.

4 The Proposed Approach to the Development of DSS in the Treatment and Maintenance of a Patient with Bronchopulmonary Diseases

The concept of CDSS is proposed, which is based on the methods of data analysis and artificial intelligence in the diagnosis, treatment and follow-up of a patient with bronchopulmonary diseases. It allows you to organize effective interaction between the doctor and the patient, form the best trajectory for diagnosis and treatment, assess the quality of life of the patient, form recommendations and monitor the dynamics of the patient's condition in the future. Personalization of treatment and patient support provides for automated comprehensive accounting of the patient's condition, described by semi-structured and poorly formalized information.

As part of the information management of a medical organization the problem of decision support is solved when managing the treatment process and accompanying the patient based on a comprehensive consideration of the patient's condition, including the emotional state during the treatment process.

The information management process includes [16]: definition of information needs; collection and creation of information; analysis and interpretation of information; organization and storage of information; access to information and its dissemination; use of information.

Below we consider in more detail the model of the decision support process (Fig. 1).

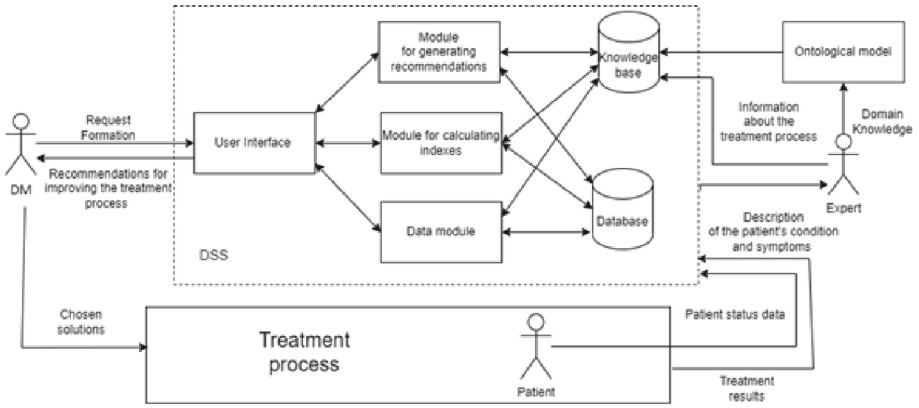

Fig.1. Scheme of the decision support process.

To increase the efficiency of the treatment process and accompany the patient from the decision maker, the selected solutions are sent to the input of this process, and the results of the process are sent to the CDSS at the output. During treatment, the patient's condition changes. Information about the patient's condition is taken into account in the DSS. The DSS includes a user interface, a module for generating recommendations, a module for calculating indicators, a module for working with data, a database, and a knowledge base. Through the user interface, decision maker forms its own requests and receives recommendations for improving the treatment process. The user interface sends requests from the decision maker to the module for generating recommendations, the module for calculating indicators, and the module working with data.

The module for generating recommendations, the module for calculating indicators and the module for working with data find the necessary information in the database and in the knowledge base upon the request received, and record there the information obtained as a result of the treatment process. The knowledge base is based on the ontological model and is filled with expert information about the subject area and system states. He also receives information from the DSS about problematic situations in the course of treatment.

This concept is distinguished by the use of artificial intelligence technologies - semantic analysis of semi-structured data of clinical recommendations and patient histories, methods of automated recognition of specific data of functional diagnostics of patients, an ontological approach to creating a knowledge base of the system for a semantic description of a poorly formalized subject area for the treatment of bronchopulmonary diseases, multi-agent technologies in modeling interaction between the doctor and the patient in the formation of the trajectory of diagnosis and treatment for a personalized treatment approach.

A feature of the system is the implementation of the following modules:

- The patient's personal profile, which will include objective and subjective indicators of the patient's condition, and will allow in the future to: analyze personal clinical risks, choose the best diagnostic and treatment trajectory, and develop lifestyle recommendations;
- The knowledge base of clinical recommendations based on the ontological approach, determined by the built dependency trees between the words in the sentence, taking into account the use of the sequence of application of the rules (which leads to the maximum convolution of the sentence) and the semantic relationship between the concepts of the sentence (which allows to implement the knowledge extraction method based on the rules from clinical guidelines);
- Medical terms dictionary, supplemented with a section with verb predicates and their synonyms, to implement the method of extracting knowledge in the form of rules from clinical recommendations;
- A multi-agent system that simulates the interaction of medical personnel with a patient during the formation of a diagnostic and treatment trajectory. It implements formalized target functions of agents and the entire system as a whole, which make it possible to evaluate performance in numerical form and compare various alternative options for diagnostic and treatment trajectories;
- Risk analysis of individual and group risks in relation to the stages of the treatment process and its participants. Based on the determination of a priori risks, risks of diagnostic and therapeutic measures, a posteriori risks associated with research results, quality of life of patients. This will allow to assess the significant impact on the results of a personalized approach to treatment;
- Mobile application to accompany the patient and control his dynamics.

5 Setting the Task in Managing the Process of Treatment and Accompanying a Patient with Bronchopulmonary Diseases

The decision support system in the treatment and maintenance of a patient with bronchopulmonary diseases will allow personalizing the treatment process, organizing effective interaction between the doctor and the patient, and reducing the risk of medical error.

In the general case, the mathematical formulation of the problem of managing the treatment process and accompanying a patient with bronchopulmonary diseases can be represented as follows:

Let X (t) = (Pi (t), Tk, Yz, Hy) - patient state vector,

where Pi (t) - patient parameters, clinical laboratory diagnostics, X-ray images, medical histories, symptoms of the disease presented in a descriptive form that require the use of special technologies for processing semi-structured and poorly formalized data;

Tк - requirements for the treatment of bronchopulmonary diseases, described by clinical guidelines, regulating considered treatment process;

Yz - the level of safety of the treatment process, which is a vector that determines the acceptable values of the risks of the considered treatment process;

Hy – patient medical history.

The patient's condition changes due to disturbing influences, external factors. Then the disturbing effect in the treatment process is a vector function. $F(t) = \{f_1(t), f_2(t),\ldots, f_l(t)\}$.

$U(t) = \{u_1(t), u_2(t),\ldots, u_m(t)\}$ - control action vector of the treatment process.

It is required to find such control actions U for a given state X that ensure the effectiveness of the treatment process in accordance with a given control criterion Q. The minimum risk of medical error can be used as a control criterion.

6 Designing CDSS in the Management of Treatment and Accompaniment of the Patient with Bronchopulmonary Diseases

To implement the proposed models, it is necessary to carry out system modeling. The SADT methodology and IDEF notation were chosen as a modeling tools.

At the stage of designing a decision support system for managing the treatment and accompaniment of the patient with bronchopulmonary diseases, a functional model of the decision support process for managing the treatment and accompaniment of a patient was developed based on a comprehensive consideration of the patient's condition. The developed functional model is shown in the Fig. 2.

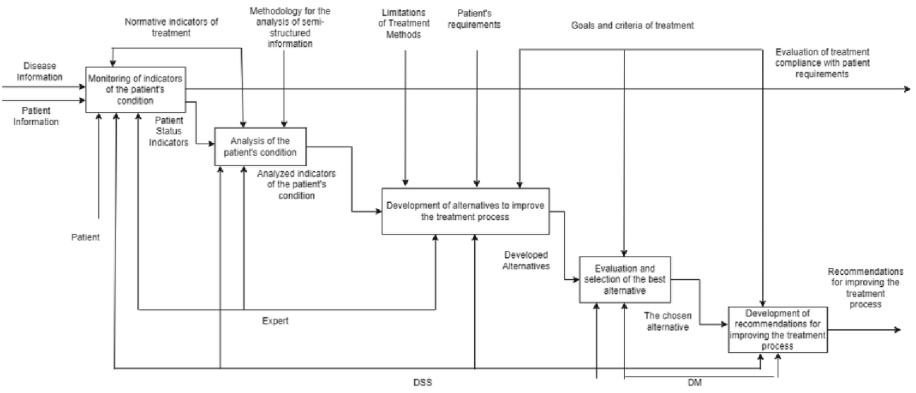

Fig. 2. Functional model of the decision support process in the management of treatment and patient support.

Decision-making support in the management of treatment and patient accompaniment consists of the following stages: monitoring of indicators of the patient's condition; analysis of the patient's condition, assessment of the compliance of the treatment process with the requirements of the patient and evaluation of the effectiveness of treatment; development of an alternative to improve the efficiency of the treatment process based

on the analyzed indicators of the patient's condition; evaluation of the developed alternatives and selection of the best of them; development of recommendations to improve the efficiency of the treatment process based on the chosen alternative.

Figure 3 shows the proposed information model of the process of providing medical services in the treatment of bronchopulmonary diseases.

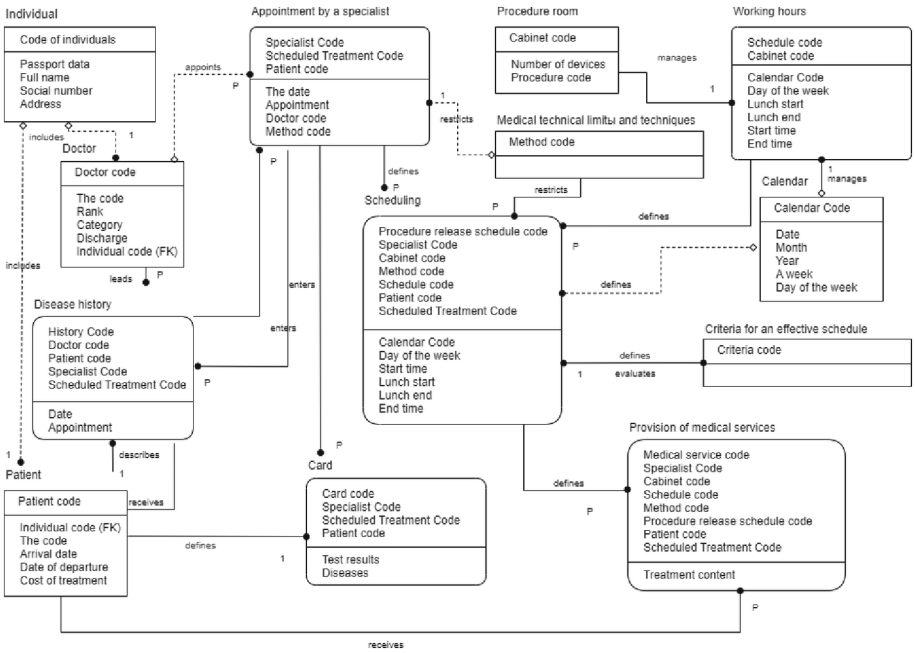

Fig. 3. Information model of the process of providing medical services.

The model highlights the main entities involved in the treatment of bronchopulmonary diseases, such as: doctor, patient (which are child entities from the entity Individual), medical record, medical history (which characterize the patient's disease), procedures prescribed by the doctor, medical and technical restrictions and methods, determining the schedule for the provision of medical services, the criterion for the effectiveness of the schedule, as well as the provision of medical services, treatment rooms, their work schedule and calendar.

The given system models formed the basis for the developed software prototypes of the proposed decision support system in the treatment and maintenance of patients with bronchopulmonary diseases.

7 Implementation of the Proposed Approach to Decision Support in the Treatment and Accompaniment of Patients

To test the proposed DSS concept in the management of treatment and follow-up of a patient with bronchopulmonary diseases, software was developed for a decision support system that implements the functions of registering patients and accompanying a doctor's appointment.

Figure 4 shows interfaces of the developed system prototype of treatment and patient support in the developed DSS.

The analysis of the developed software confirmed the relevance and necessity of creating a DSS, which will allow to achieve effective interaction between the doctor and the patient, to form the best trajectory for the diagnosis and treatment of diseases, to interactively assess the quality of life of the patient, and with the help of knowledge bases and technologies of semantic analysis to form recommendations and carry out monitoring the dynamics of the patient's condition.

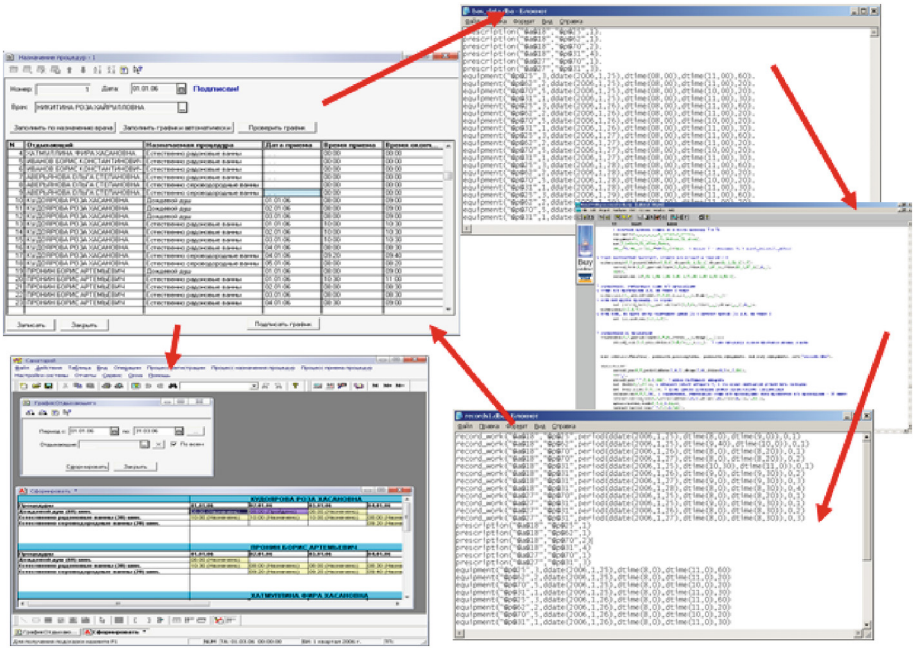

Fig. 4. Interfaces of the main stages of treatment and patient support in the developed DSS.

8 Conclusion

Decision support systems are actively used in many areas, in particular in medicine, as they can also help in saving a person's life by correctly analyzing the available data about the patient, his disease, methods of its treatment, as well as reduce the risk of medical errors.

An analysis of the capabilities of artificial intelligence tools for decision making support in the process of treating and accompanying a patient with bronchopulmonary diseases, with a comprehensive consideration of the patient's condition, showed their applicability for decision support systems in medicine. A mathematical statement of the problem of managing the process of treatment and accompanying a patient with bronchopulmonary diseases was formulated. A landscape of medical organization processes (process map) and a decision support scheme was developed. At the design stage of the information system, a functional decision-making support model was developed for managing treatment and support of the patient, which serves as the basis for developing software for the proposed DSS.

The proposed concept of DSS in the treatment and maintenance of patients with bronchopulmonary diseases is distinguished by: the integration in the implemented modules of the system of semantic analysis of semi-structured data of clinical recommendations and patient histories, methods of automated recognition of specific data of the patient functional diagnostics, the knowledge base of the system, which based on the ontological approach for the semantic description of a poorly formalized subject of bronchopulmonary diseases treatment, multi-agent technologies in modeling the interaction between a doctor and a patient to form a personalized approach to the trajectory of diagnosis and treatment.

To implement the proposed concept of a decision support system in the management of treatment and support of a patient with bronchopulmonary diseases, at the next stages it is planned to develop models and methods for analyzing data and artificial intelligence necessary for organizing effective interaction between a doctor and a patient, forming the best trajectory for diagnosis and treatment, and assessing the quality of life patient and monitoring the dynamics of the patient's condition over time.

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