

# ABOUT DESIGN MEDICAL DATABASES AND INFORMATION SYSTEMS FOR THE ORGANIZATION AND MANAGEMENT OF CLINICAL PROCESSES

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## ABSTRACT

In article questions of development of automated, integrated information systems and databases (DB), created by the authors to ensure that the information and intellectual support of organizations and management of clinical processes in a general hospital. Analyze the schema information and intellectual support for the main stages of activity of the doctor in the organization of clinical processes and proved the effectiveness of the transition to electronic document management and management of patient records. The techniques and steps in the process of designing a database of such systems. Presented data models based on relational principles and taking into account the peculiarities of information provision of medical care in a clinical hospital emergency medicine. Sanctified issues for creating a database implemented taking into account the specifics of health care regulations, standards and related problems of formalization and standardization of information, the problem of choice of database management systems (DBMS), including for medical applications, the issues of intellectualization of the database and the formation of a knowledge base. Showing crucial modeling domain – automation object articles in this case – the diagnostic and treatment process. The main requirements to the database integrated health information systems. Questions of formalization entered

into the database of medical and other information, the solution of which the authors carried out through the creation of special electronic templates for all aspects of medical practice hospital. Being developed by leading medical specialists clinic, they do not only facilitate the design, but also remind us that we should find out, to ask to examine and help select the best tactics. This kind of technology is human-computer interaction – an element of the programming actions of the doctor. This option is the task of formalizing entered into the database of medical information used to provide a single standard of medical information, standardize the order of the information entered into the database. The results of the analysis of the effectiveness of the developed information system and performance of its database in the course of their use in the clinical setting. In particular, we studied the performance, response time and server load when working with different categories of users – doctors, nurses, administrators, and etc., which have shown the applicability of the developed health information system and its database to optimize the organization of clinical processes in the conditions of the experiment.

**KEYWORDS:** *medical information systems, electronic medical records, databases, knowledge base, intellectual support, workstations, information technology, medical-diagnostic process.*

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In modern medical treatment institutions (TI), huge volumes of medical data are formed and accumulated, and the quality of the medical care they provide depends on how timely and efficiently this information is used by doctors, specialists and heads of institutions. To optimize the organization of treatment and diagnostic processes (TDP) and the management of LU activities, it is especially important not only to use the accumulated information as efficiently as possible, but also to use the implicit trends and patterns hidden in them, revealed with the help of special analysis, and in the case of emergency medicine and ensuring the required speed of information processing and transmission. The solution of these problems determines the relevance of the creation and use of automated information-analytical and communication systems in clinical practice.

Note that a medical information system (MIS) is a set of software and hardware tools, databases and knowledge that, having a number of functional capabilities, with the presence of appropriate networks, allows you to automate the organization and management of LDP, go to electronic document management and maintain an electronic medical history (EMH) [1, 13]. It also allows you to provide information and intellectual support for the adoption of medical and managerial decisions, analysis and control of the work of institutions, as well as optimize the use of its resources.

Usually such systems deal with large amounts of information with a rather complex structure. We present the recommended [14] schemes of informational and intellectual support of the physician's activity (Fig. 1), which provide for the main stages of medical activity in organizing the LDP.

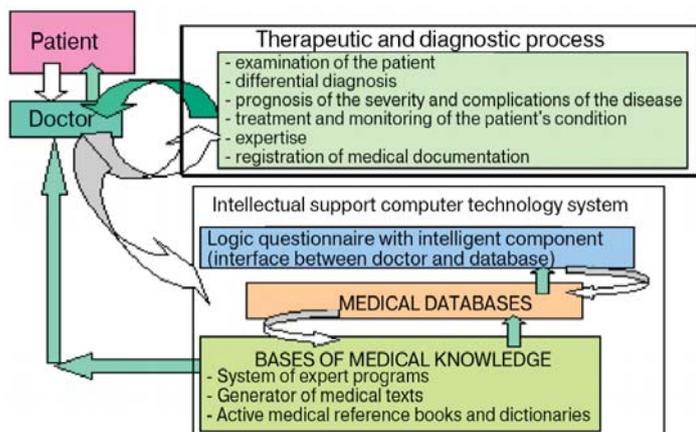


Figure 1

Almost all such systems are to one degree or another associated with the functions of long-term storage of database information (DI) - a machine tool for accumulation and storage, as well as the organization of large data arrays, on the basis of which all problems of the domain (software) are solved. Databases allow you to store patient data and collected medical data. During the observation of the patient, the records in the database are updated with data from current examinations, consultations, consultations and examinations. Therefore, the database should be able to accumulate, store and update data, as well as provide various categories of users with quick access to the required data.

To do this, the data in the database must be structured and organized in accordance with some model of the subject area, which is a collection of objects, their properties and connections between them.

This paper presents the basic principles used in the design of the database of the complex information-analytical system ExterNET and its EIB, developed by us for the automated organization and management of treatment and diagnostic processes [8, 9]. This system has been introduced into clinical practice in a multi-profile hospital (350 beds) of the Fergana branch of the Republican Scientific Center for Emergency Medical Aid (Uzbekistan).

Comprehensive computerization of medical institutions, the creation of specialized integrated medical information technology systems and networks, in addition to the development of a general methodology, requires the elaboration of a large number of specific issues. These include the problems of electronic document management, implemented taking into account the specifics of medical regulations and standards, and related problems of formalization and standardization of information presentation; problems of choosing database management systems (DBMS), including those for medical applications; issues of database intellectualization; formation, on the basis of the information contained in the database, "operational" and "analytical" forms of information; reliability and safety issues; problems of transition to completely digital technologies with the possibility of automated data analysis, as well as a wide range of issues related to horizontal and vertical integration of information, etc.

Traditionally, medical records are kept in the form "Human readable" text and are designed to be read, processed, evaluated and analyzed by a person, a medical officer. This method of information processing is still the main one in the treatment and diagnostic process.

Automated processing puts forward additional requirements for the maintenance of medical information, namely, its formalization and coding. Formalization and coding of information provide tremendous advances and advantages of computer processing [3].

Formalization in this case means the structuring of information, dividing it into specific sections and subsections, up to highlighting the signs and attributes of each medical entity and a clear description of all these signs in a medical document.

Thus, the design of an integrated subject-matter, integrated into a large-sized database, which is the database of complex clinical information systems, is a difficult task [2, 4-6].

Database design is an iterative, multi-stage process of making informed decisions in the process of analyzing the software information model, data requirements from application programmers and users, synthesizing logical and physical data structures, as well as analyzing and justifying the choice of software and hardware.

The main tasks of designing a database are: ensuring the storage of all necessary information in the database; ensuring the ability to obtain data on all necessary requests; reduction of redundancy and duplication of data; ensuring data integrity (correctness of their content): elimination of contradictions in data content; elimination of data loss, etc.

In accordance with these tasks, in the design of databases and their operation, the following general requirements are imposed on them:

- the adequacy of the display of the subject area (completeness, integrity, data consistency, relevance);
- the ability to interact with users of different categories;
- ensuring high efficiency of access;
- user-friendliness of the interface;
- ensuring secrecy and confidentiality;
- ensuring the mutual independence of programs and data;
- ensuring the reliability of the database;
- data protection against accidental and deliberate destruction;
- the ability to quickly and completely restore data in the event of their destruction;
- in the case of corporate databases - ensuring maximum opportunities for each user, that is, supporting the performance of all business functions by an employee who receives the final result.

The database development process can be divided into several stages: research of the subject area; creation of an infological (information-logical) model; creation of a datalogical model; creation of a physical model.

The most important stage in the design of a database is the development of an infological model of the domain that is not focused on the DBMS. In the infological model, by means of data structures in an integrated form, the composition and structure of the data, as well as the information needs of applications (tasks and requests), are reflected. This model reflects the subject area in the form of a set of information objects and their structural links.

Information about the subject area that users work with is displayed first in the infological model, then in the datalogical and physical models. The views of individual users are formed by external infological and datalogical models. What tools can be used to compose an infological description of the subject area? There is no single answer to this question.

There are several techniques and, accordingly, different tools are used. The compiled model should be simple, clear, contain all the information for further design stages, and easily be converted into database models for common DBMS. Based on these requirements, the described design method uses a model called "entity-relationship" (or "objects-relationship").

When designing a database, methods for performing such design stages as collecting information about software, choosing a language for representing the so-called "semantic" model for fixing information about software, their subsequent analysis, and synthesizing a database model were also realized and integrated into well-structured schemes.

Analysis of the collected information about software provides for: classification, formalization and integration of structural elements of software description, formalization of both structural and procedural constraints on the integrity of elements in the future software model, determination of the dynamics of instances of software objects.

The synthesis of the conceptual model of the database includes:

- designing an integral conceptual database schema in the selected semantic modeling language;

- choice of a specific data model and DBMS for DB implementation;
- designing a logical database scheme for the selected DBMS (also called "implementation design");
- development of the physical structure of the database ("physical" or "internal" scheme, it is also - "layout"), including the placement of the database by nodes;
- development of technology and procedures for the initial creation and filling of the database;
- development of technology and procedures for database maintenance;
- development of universal database access programs and corresponding user interfaces;
- database testing, its development and improvement (tuning) of its structure.

conceptual design is the collection, analysis and editing of data requirements. For this, the following activities are carried out:

- survey of the subject area, its study information structure;
- identification of all fragments, each of which is characterized by a user view, information objects and connections between them, processes over information objects;
- modeling and integration of all views.

At the end of this stage, we get a conceptual model that is invariant to the database structure. It is often represented as an entity-relationship model.

At the stage of DB development, the DBMS serves to describe the structure of the database, i.e.: defining tables, determining the number of fields, the type of data displayed in them, the size of the fields, determining the relationships between tables.

In addition to tables, most DBMS provide for the creation of special tools for working with data - forms, queries.

During the operation of the database, the DBMS provides editing of the database structure, filling it with data, searching, sorting, selecting data according to specified criteria, and generating reports.

Now we will try to create a complete infological model of the "Case history" problem. For this, we list the rules that the entity-relationship model must satisfy:

- the model should give a complete picture of the subject area;
- all entities necessary for the implementation of the task and their attributes should be listed, respectively;
- the names of entities must be unique;
- the names of attributes within the same entity must be unique;
- we must guarantee an unambiguous interpretation of the model;
- in each entity, an identifying set of attributes must be highlighted;
- the model must be flexible, i.e. when new tasks arise, expand without significant changes to the existing model.

The model presented in Figure 2 allows solving the main tasks of the medical history. It is one of many possible solutions.

An identifying attribute (identifying a set of attributes, ISA) is an attribute (several attributes), the value of which determines the uniqueness of an entity instance.

Almost all modern systems are based on a relational database management model [7].

In a relational database management system, all processed data are presented in the form of flat tables. Information about objects of a certain type is presented in tabular form: various attributes of objects are concentrated in the columns of the table, and rows are intended to reduce descriptions of all attributes to individual instances of objects.

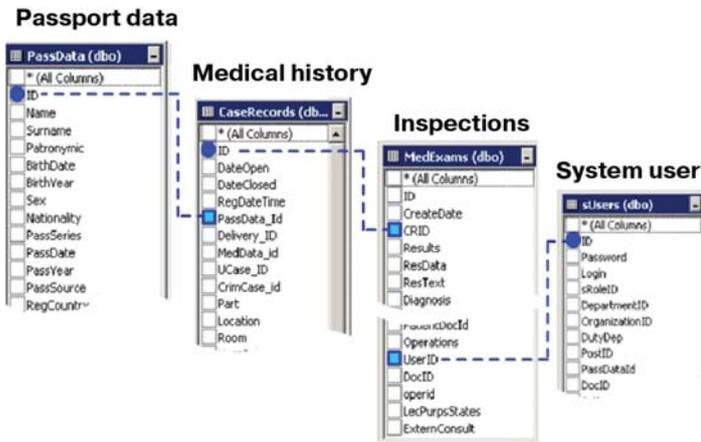


Figure 2. Key model of identifiable attributes

The model, created at the stage of infological modeling, most satisfies the principles of relativity. However, to bring this model to relational, you need to perform a procedure called normalization.

Normalization theory operates with five normal forms. These forms are designed to reduce the redundancy of information, so each subsequent normal form must meet the requirements of the previous and some additional conditions.

Rational variants of the conceptual DB schema must satisfy the third normal form, as well as the following requirements: the selected list of relations must be minimal; the relationship is used if only its necessity is caused by the tasks; the selected list of attributes should be minimal; an attribute is included in a relationship only if it will be used.

The primary key of the relationship must be minimal. That is, it is impossible to exclude any attribute from the identifying set of attributes without violating the unambiguous identification. When performing operations on data, there should be no difficulties.

Datalogical and physical models are directly implemented in the DBMS. At the same time, the physical model defines the structure of data storage on physical media.

The specifics of a particular DBMS may include restrictions on the naming of database objects, restrictions on the supported data types, etc. In addition, the specificity of a particular DBMS in physical design includes the choice of solutions related to the physical environment of data storage (choice of methods for managing disk memory, dividing the database by files and devices, methods of accessing data), creating indexes, etc.

At each design level, information is structured in such a way that at the third level information can be presented in the form of

data structures implemented in the computer memory. In this way:

**At the first level**, which is called infological, it is determined what information about the subject area will be stored and processed in the computer, and as a result of researching the subject area, its infological model is built. Information in the infological model is presented regardless of what software and hardware will be used in the future to store and process it. At this level, the domain is described in terms of object classes and their relationships, which are understandable to end users and people working in the domain who are not familiar with the principles of database organization.

**At the second level**, which is called datalogical, or conceptual, information is presented in the form of data and logical connections between data, regardless of what the data is and what technical means will be used to store the data, but taking into account software tools (DBMS). There are several types of datalogical data models: network, hierarchical, relational, object, and others.

**The third, physical, layer** defines how and where data will be stored on the physical medium.

Our important decision was the rejection of the design of the MIS database by functional purpose, when a separate database was created for a separate task (for example, a laboratory subsystem, pharmacy, functional diagnostics, consultation, etc.). Although this approach has a number of advantages, the main one of which is to reduce the requirements for the hardware power of the server by dividing the streams of user requests to separate databases. We chose to design the MIS database in such a way that all information was collected around the patient and physically stored in one database (Fig. 3).

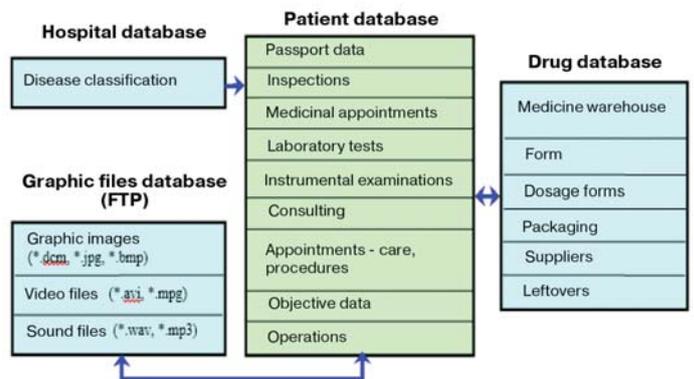


Figure 3. The enlarged scheme of the object-relational database of the medical information system

Designing the structure of the database, thus, allows you to achieve a stably small volume of the MIS database during almost the entire period of its operation, and thereby ensure the maximum possible performance of the MIS. The complexity of this technique is that the software of the information system must support any number of physical databases in the core of the system, combined into one logical structure.

Thus, it is necessary to develop algorithms for all MIS programs so that they can work correctly with a database of current

documents, consisting of one or more parts. This is due to the fact that in some cases the program needs to process data not only for a separate part of the database, but also for all the information available in it.

To effectively solve this problem, it is necessary to exclude direct reference to the database in the texts of MIS programs. Instead, it is proposed to use special middleware called services middleware.

Figure 4 illustrates the interaction of the user, the DBMS and the OS when processing a request to receive data. The numbers indicate the sequence of interactions, namely:

1 - The user sends the DBMS a request to receive data from the DB.

2 - Analysis of the user's rights and the external data model corresponding to this user confirms or denies the access of this user to the requested data.

3 - If access to data is denied, the DBMS informs the user about it (arrow 12) and stops further data processing, otherwise the DBMS determines the part of the conceptual model that is affected by the user's request.

4 - The DBMS receives information about the requested part of the conceptual model.

5 - The DBMS requests information about the location of data at the physical level (files or physical addresses).

6 - The DBMS returns information about the location of the data in terms of the operating system.

7 - The DBMS asks the operating system to provide the necessary data using the operating system tools.

8 - The operating system pumps information from storage devices and sends it to system buffer.

9 - The operating system notifies the DBMS about the end of the transfer.

10 - the DBMS selects from the delivered information,

11 - Located in the system buffer, only what the user needs, and sends this data to (12).

12 - User work area.

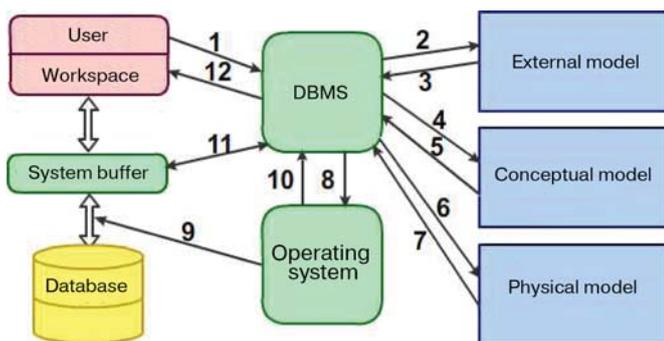


Figure 4. Scheme of passing a request to the database

Data structuring is based on concepts "Aggregation" and "generalization" (Fig. 5).

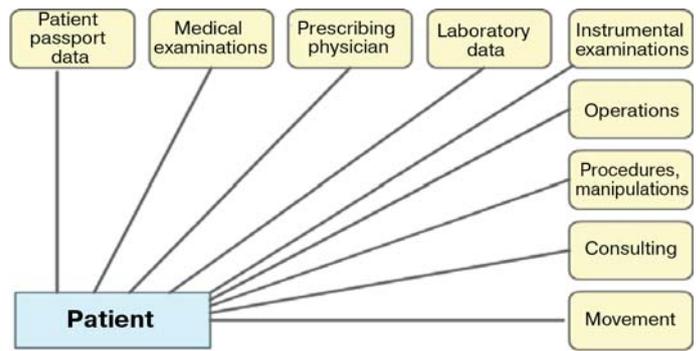


Figure 5. Data structuring

Diagram in Figure 5 defines the composition order of the data structures of this model. A data element is the smallest named unit of data (analogous to a "field" in file systems) to which the DBMS can be addressed directly and with the help of what builds all other structures. The item name is used to identify it in the high-level data structure schema. A data aggregate is a named collection of data items within a record that can be viewed as a whole. A set is a named collection of records that form a two-level hierarchical structure. To implement the possibility of presenting such information in the model, it is necessary to organize the appropriate connections between the patient and doctor entities.

Ensuring the performance of the OBD remains a challenge. At the same time, the determination of the time characteristics of working with the database and ensuring the preservation of these characteristics during the operation of the database are among the most difficult design tasks. It is well known [10] that the following main indicators are used to analyze the efficiency of an information system for any purpose:

- 1) performance of the information system, expressed in the number of operations performed per unit of time;
- 2) response time of the information system;
- 3) load of the information system server (percentage of server processor utilization).

Table 1

### General information about the load on the MIS

Indicators	Information read (kb)	Information recorded (kb)	Updated information (kb)
General data (work of 50 users)	1239650.80 (±503499.50)	40483.20 (±29784.90)	10438.10 (±10564.50)
Per user	27493.01 (±13013.40)	809.66 (±794.264)	208.76 (±281.72)

The analysis showed that during the study period, doctors used the capabilities of MIS to 100%, nurses 80% of MIS capabilities were used, users of para-clinical department - 75%, users of administrative and managerial status - 20%, system administrators - 100%.

With a clinic occupancy of 80%, on average, doctors look through 280.03 (± 149.0) EIB per day, of which 83.20 (± 48.3) add records (examinations, appointments, manipulations, etc.). Nurses look at 417.10 (± 216.7) EIB per day, record at 178.50

(± 111.50). Taking into account the actual use of the system, these indicators for healthcare facilities with a full transition to EIB can increase to 542.23 EIB per day.

For each doctor in clinical departments, the information system processes 21176.60 (± 11526.10) kbytes of information per day, which is 68.4% of the total volume of the database. In the "pharmacy" module, 37136.40 (± 18326.2) kbytes of information were processed for each doctor.

Thus, the most resource-intensive operation is the operation of obtaining and recording information about patients by doctors and nurses. During the execution of this operation, the DBMS executes a number of complex subqueries that require significant computational resources:

1. Checking user access rights to the database;
2. Downloading programs and objects to the user's client workstation, taking into account his access level;
3. Loading of interface elements used for the operation of applications, including graphic files of instrumental and laboratory analyzes, etc.;
4. Opening the database, which is an update of all views in it, taking into account the changes that have occurred after the last execution of the command to open the database and taking into account the current user access level;
5. Transfer of the list of documents generated when opening the database to the user's client workstation;
6. Processing of the received list, client informing and working data about patients, and displaying it on the screen.
7. Formation of a list of medicinal products from the database of pharmacy and department warehouses.
8. Formation of a template for examinations at the doctor's choice from the examination database.

As can be seen from the above list, the operation of connecting to a database widely uses the most various types of requests and operations for exchanging information between a client workstation and an information network server. Thus, the time of connecting to the database can adequately characterize the effectiveness of the applied methodology for designing the database structure.

A wide range of different types of requests are used in the work of the IIA. In order to determine their characteristics under the conditions of an operating MIS "ExterNET", a chronometric study was carried out [10], the results of which are shown in Table 2. During the study, the operation time of some basic types of requests was measured, for which, during the execution of MIS software commands, the time after submission of a command by the user and the time of outputting the result of work on the screen. The difference between the indicated time intervals was recorded in a special database table using a specially created program during the study, and at the end of the study, the average value of the query execution duration and the number of queries executed per day were calculated. At the same time, the server processor load indicator was recorded during this period of time.

It was revealed that the greatest load on the information system is provided by the doctors of the departments, therefore, for the analysis, only requests from their client workstations were taken, which were executed at the time of simultaneous servicing of 50-55 users by the server. These measurements were repeated

many times and their average values were taken into account. As can be seen from Table 2, the highest server load and the highest response time were recorded when executing requests for the formation of templates for inspection. However, the use of this type of request can be canceled at the request of the user, but with a template filling out the examination, the doctor needs less time to complete the examination than in the arbitrary option of filling out the examination of the patient. The template form for filling out inspections has other advantages.

Table 2

### Characteristics of the main types of requests in "ExterNET"

Request Description	Average execution time, sec.	Average frequency of execution, per day	Average server processor load during query execution, %
Database connection, user identification	5.2	72.1	19.2
Database connection with data archives	2.2	2.8	17.2
Formation of the list of patients in the department	0.5	152.6	16.3
Formation of complete data about the selected patient	0.5	588.7	10.8
Recording a new inspection to the database	0.6	278.7	11.2
Adding or updating patient medical data to the database	0.4	101.8	5.4
Generate inspection templates	10	278.7	15.8
Database connection with laboratory data	0.4	458.1	5.7
Connection to the drug database	2	278.7	8.4
Connection to database	0.3	278.7	7.8
Connecting to an FTP server to receive video and graphic files in instrumental and laboratory examinations	1	41.2	4.2

The use of electronic media requires the formalization of the information entered. We achieved this goal by creating special electronic templates for entering information into the database at all levels of care provided, whether it is medical information, nursing, or the result of an additional examination. The term "template" does not mean either a stencil description or a stereotyped patient management.

This is a specially prepared set of medical terms and expressions for the design of a medical examination, diaries, epicrisis, description of the results of laboratory and instrumental examinations, etc. Developed by the leading medical specialists of our clinic, they not only facilitate registration, but also remind you to find out, ask, examine and help you choose the best tactics.

This is a kind of technology of human-computer interaction - an element of programming the doctor's actions. As a result, we not only achieved the maximum formalization of the input information, but also streamlined the sequence of their input into the database.

This option for solving the problem of formalization entered into the medical information database has the following advantages:

1. A unified standard of medical information used is achieved.

2. The order of information entered into the database is standardized (medical examination, prescriptions for treatment, examination, choice of treatment tactics, results of measuring the patient's objective parameters, etc.).

In connection with the above, the main condition for the application of the technology developed by us is the use of electronic templates by the doctor when registering his examination. In this case, all medical records have a strictly defined structure and contain only formalized medical information. When recording a medical record in the postoperative period, the information automatically goes through software processing through the adopted algorithm.

With the help of formalization, it is also possible to build expert systems to provide intelligent assistance to doctors in diagnosing and choosing treatment tactics. Formalized EIB makes it possible to continuously accumulate information on a specific pathology and to analyze the further course of treatment according to the recommended criteria. Over time, the MIS will accumulate a knowledge base (KB), which will be constantly replenished, and the system itself will use it in the tasks of diagnostics and the choice of treatment tactics [11].

Note that the knowledge base is, in our case, a set of units for achieving medical knowledge, logical rules and algorithms, which are formalized, using a certain method of representation, knowledge, reflecting objects of the subject area and their interrelationships [12]. They provide the ability to form and output medical opinions and recommendations based on the system of decision-making algorithms embedded in it. The medical knowledge bases contain text synthesis scripts for medical history and other medical documents, automatically generated by the generator of medical texts based on the collected patient data.

## Conclusions

Thus, in the single information space of the emergency medical care center created on the basis of ICT and its database, only formalized and reliable information is formed, generated, and transported through information channels, in the required volume, in a strictly orderly manner, preventing information disorder, providing each participant in the process of providing emergency medical care information and intellectual support necessary to fulfill their functional duties, covering at the same time specialists from the lowest level to the first head of a medical institution.

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