Automated information system for the rehabilitation of post-stroke patients in residual period

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Abstract. The article outlines the theoretical and practical aspects of the development of new approaches for improving the effectiveness of health care based on information computational technologies. A medical information system for the process of rehabilitation and rehabilitation of post-stroke patients was designed and implemented, based on structuring each of the levels according by relevant criteria, which allows to take into account the effect of endogenous and exogenous risks of patients' therapy in residual period.

Keywords: medical information system, post-stroke patient, automated computer system, rehabilitation process, program complex, infological scheme

1 Introduction

Medical information systems (MISs) and technologies provide intellectual support for the physician's activities, speeding up the decision making while improving the quality and reliability of the treatment tactics. This is particularly important for the area of treatment of patients with disorders of cerebral circulation, the number of which is increasing worldwide every year. Among the causes of primary disability of the adult population, stroke ranks the second position. In the structure of total mortality stroke accounts 11.1 %, sharing fifth position with diseases of the nervous system, which is one of the highest indexes in the world [1].

According to the data of the World Health Organization, 4.6 million people die of a stroke every year, which is 9-12 % of all causes of death. Among adults, 25 % of cases of disability are due to stroke, and only 10–20 % of stroke patients return to work. After a stroke the cognitive impairment, hemiparesis and speech disorders are

observed in 33 %, 30 % and 27 % cases, accordingly.

Neuro-rehabilitation can be classified according to the duration of the recovery period as follows: a) an early recovery period - up to 6 months after the acute phase of the disease; b) late recovery period - from 6 months to 1 year after the acute phase of the disease; c) residual period - after 1 year [2]. The post-stroke treatment of patients is complicated task which requires the development of novel approaches including information computational technologies.

2 Literature review

The systemic study of the residual period of post-stroke rehabilitation was not conducted in Ukraine previously. In particular, the risks in the rehabilitation period were not classified. The concept of monitoring the health status of post-stroke patients was not developed while the principles of the continuity of rehabilitation activities were not worked out. Notably, there was no specialized medical information systems focused of post-stroke patients' rehabilitation.

The development of medicine, focused on rehabilitation and maximum restoration of human functional capabilities, includes new approaches for building up-to-date information technologies for managing sanatorium-resort activities [3-5]. Among the current problems there is the creation of integrated informational systems aimed to optimizing information flows for bringing up the medical care to a new level [6, 7].

Despite the achievements in this field [8-11], the high efficiency of information support in the rehabilitation process during the residual period was not reached yet. This could be possible on the basement of integrating the medical treatment/rehabilitation process with computer models, algorithms and other hardware/software tools. This link allows to record, analyze and process the information in order to find appropriate strategy for patients in the residual period.

Recent studies showed that in the residual period there is a fairly large number of ambiguities. This is due to the fact that in the period from 1-2 years to 3-5 years after the acute phase of the disease, its clinical picture may differ significantly for different patients [1]. In this connection, the concepts of "early residual period" and "late residual period" were proposed for implementing into clinical studies and practice [12, 13]. It is emphasized that the main task of neuro-rehabilitation (especially in the later period) is to maintain and stabilize stroke patients for improving the quality of their health [14]. The resolving of the problem of informatization of post-stroke patients' rehabilitation is possible only on the basement of up-to-date information systems and technologies.

There are a number of known information systems used for managing the health care institutions [15, 16]. The "Institute of Medical Rehabilitation Problems" has developed an automated information system for supporting rehabilitation treatment for patients with disorders of the musculoskeletal system. This system covers the process from optimizing the patient's entrance examination to formulating the recommendations on appropriate rehabilitation procedures [17]. The software core of the information system is adapted to the specifics of the treatment/rehabilitation process,

focusing on setting up the workplaces with a wide range of new functionalities.

An automated computer system was developed in "Research Institute of Medical and Social Expertise and Rehabilitation" to predict the results of rehabilitation for cerebral stroke and for traumatic brain injury [12]. This automated system allows to consistently solve the tasks as: (a) the prediction of the results of rehabilitation at different periods of the disease; (b) the probabilistic prediction of outcome of rehabilitation using differentiated diagnostic indicators; (c) the selection of the optimal rehabilitation measures depending on the period of the disease and severity of functional disorders; (d) the developing patients databases with the possibility of statistical processing the results of the examination and rehabilitation; (e) formulating and printing the forecast and recommended rehabilitation measures. The mentioned system offers the physician the tactic of medical rehabilitation taking into account the period of the disease, the functional class of disorders/disability and the clinical and rehabilitation prognosis. The use of this system allows to adequately predicts the outcome of rehabilitation for cerebral stroke (traumatic brain injury) in the early stages. This leads to formulating an optimal set of rehabilitation measures aimed at the maximum reduction in the patient's disability.

However, the above mentioned medical information systems do not take into account the risks and specifics of the residual period of post-stroke patients. The aim of the paper is to develop an adequate medical information system for the rehabilitation of post-stroke patients in the residual period, focusing on effectiveness of the quality of the rehabilitation and recovery process of post-stroke patients.

3 The structural organization of MIS for the management of rehabilitation treatment of post-stroke patients

The development of a medical information system is based on a specific set of the design principles such as:

- the subject area of MIS functioning is determined by the triad "Patient - Disease – Diagnostic/ Therapeutic Process". A feature of the subject area is the ability to change the relevant fragments of the system as well as its functionality;
- focusing on medical personnel, which has a fairly high user level relative to computing technology and complex biomedical equipment.

The principle of "New tasks" and the principle of "First leader" were implemented as basic principles for MIS designing [18].

The principle of "New tasks" assumes that the system developers should be sufficiently acquainted with the subject area and the peculiarities of the functioning of information system [4]. The principle of "First leader" requires the participation of the head of the institution in the process of development and implementation of an information system. This is connected with the need of understanding the problems which could be caused by implementation of computer system with further managing decisions made by the first manager.

MIS should comply the following design principles: comfort for user, modularity,

adaptability, functional completeness, openness of the system. The block-diagram of developed MIS for sanatorium-resort rehabilitation of post-stroke patients is shown in Figure 1.

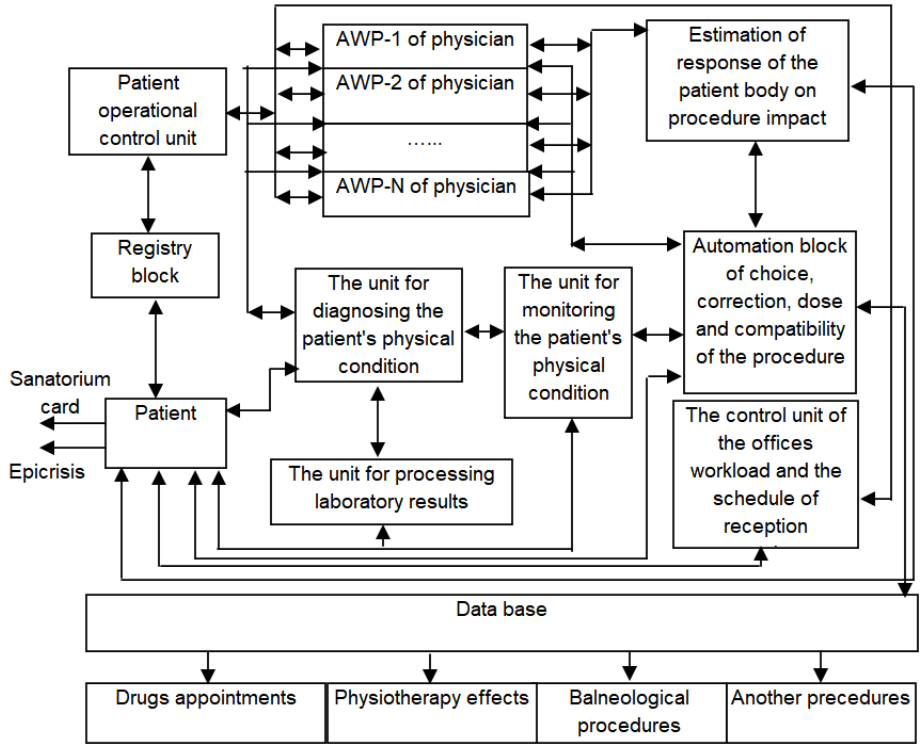

Fig. 1. Structural diagram of the operational dispatch management of post-stroke patients' rehabilitation

The main feature of the health care system in sanatorium-resort institutions is the close intersection of management tasks and medical care technology, which are based on the use of resort factors.

4 Functional organization of MIS

The complex of functional capabilities of MIS is formed on the basis of the requirement to reduce the risks predicted for each of the components of the triad "Patient - Disease – Diagnostic/Therapeutic Process" [19]. The features and capabilities of the created MIS are:

- MIS ensures the formation and management of patient flows having disorders of the musculoskeletal system, which require specific approach for rehabilitation tactic;
- MIS contains the complex of information support for modern telemedicine technologies and formation of medical electronic passport of a patient;

- MIS is able to analyze and forecast medical and financial activities of a sanatorium ensuring optimal management in order to reduce the medical and financial risks.

Application of designed MIS provides post-stroke patients with the following options:

- focusing on quantitative and qualitative assessment of the functional and adaptive capabilities of the human body for the health restoration/correction in order to elevate patient's social status;
- a significant improvement in the quality of health care services through the information interaction between doctors and specialists taking part in the treatment of the patients;
- continuous monitoring and using the patients' database through a personal medical electronic passport;
- formation of individual or personalized programs of rehabilitation and medical prevention, both primary and secondary;
- the use of common criteria for assessing the effectiveness and adequacy of therapeutic and rehabilitation/recreational activities in the clinic, sanatorium and at home.

Ultimately, this leads to an increase in health quality, to prolongation of professional activity, to decreasing premature mortality and disability, to increasing the duration and quality of life.

In turn, the authority of the sanatorium is provided by MIS with the following:

- operational information about the health and functional level of both patients and staff; about the course of the treatment and rehabilitation process; about condition and dynamics of medical place capacity;
- the results of the analysis of the causes of non-compliance with medical prescriptions with further correction of individual treatment and rehabilitation schemes in compliance with medical standards;
- the ability to control and manage the medical, financial and other activities of the sanatorium with the aim of rational targeted expense of financial resources;
- the protection of all medical, financial and other information from unauthorized access;
- the possibility of saving and the subsequent redistribution of financial resources by optimizing the structure of the sanatorium, medical-diagnostic and rehabilitation processes, eliminating duplication of expensive research and appointments.

MIS supplies the medical staff of the sanatorium with the opportunity to ensure the high quality of treatment and rehabilitation of post-stroke patients due to:

- prompt receipt of the necessary information in a standardized form about medical appointments and procedures, results of diagnostic, clinical and other studies, etc.;
- information support of the processes of treatment and decision-making to determine the strategy of treatment of each patient individually;
- informational support for choosing and controlling the therapeutic process with providing the drugs, physiotherapeutic and balneological procedures, etc.;
- information support for the distribution of medical and rehabilitation procedures between the patients taking into account work schedules and workload of the respective medical rooms;
- elimination of duplication of diagnostic studies, procedures and medical prescrip-

tions;

- controlling the performance of staff functional duties by the management;
- controlling the supply and using the medical drugs.

5 User interface

MIS is designed as a computer program “Registry of the automated polyclinic” for automate maintenance of the registry in the clinic. It is aimed at increasing the reliability and efficiency of receiving and controlling the patients flow. Some of the program’s windows are shown in Fig. 2 and Fig. 3.

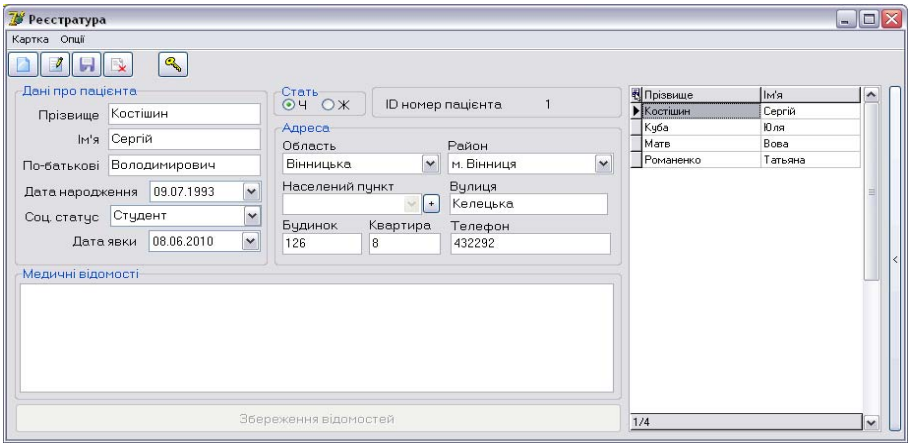

Fig. 2. The window of the module “Registry of the automated polyclinic”

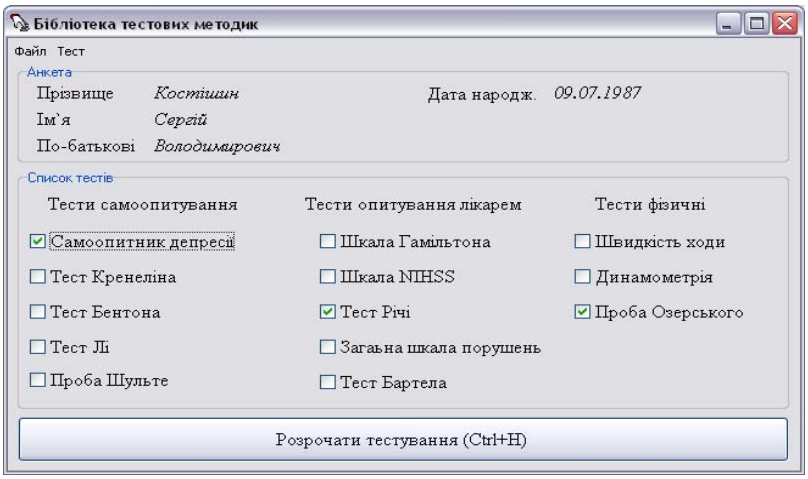

Fig. 3. The window of the testing methods’ kit

The program “Registry of the automated polyclinic” allows to enter information about patients into the database providing the doctor with necessary information about the patient. It also provides an effective control of the workload of the clinic.

The program allows a convenient widescreen search on such criteria as the family name, date of birth, the region and the area of the residence etc. These parameters can be used when searching both individually and in a complex.

The fields used in the program are the patient biography, address, contact information and medical information about his visits to clinic, information about examinations, diagnoses, previous Botkin's disease, the fluorography, the severity of diabetes and other necessary information.

After these data are entered and stored in a database, they become accessible to any user from any workstation under appropriate access right. Under the first program run the connection to server database is needed. On subsequent runs the connection will occur automatically.

The program complex involves thirteen test methods, five of which are classical, which the patient must undergo, and five more are the test methods that the doctor must consider, basing on the survey and examination of the patient. Three more methods are the physical tests to indicate the patient health state.

The structure of the physical test is different, since it is envisaged that the patient will pass it separately. Therefore the only thing that interests the doctor is the result of the test and the date of its passage.

6 Automated workplace (AWP) of the neurologist

The hierarchy of every medical system includes several levels such as regional, medical institution and local (the human body). Each of them is characterized by its own functioning laws and the range of tasks [20].

At the local level, automated systems are widely used to improve the efficiency and quality of medical care due to computer collecting, processing, storing, presenting and using medical information necessary to adequately address diagnostic and treatment tasks.

As a rule, for each patient, all stages of the therapeutic and diagnostic process are to be reflected in chronological order in certain medical records. The doctor and other medical staff involved, make new records reflecting the nature of their activity and its specific results. A typical infological scheme of the doctor’s automated workplace and informational interconnections between the individual components are presented in Figure 4.

The diagnosis formulated for various diseases is formed in a single format which reflects: the etiology of the disease; clinical (clinical and morphological) version of the disease; phase of the disease (remission, exacerbation, etc.); flow stage (initial, unfolded, etc.); some of the most pronounced syndromes; complications.

An important step in the development and operation of the doctor’s AWP is certification of the AWP, which is carried out at three levels: technical, organizational, and in terms of working and safety conditions.

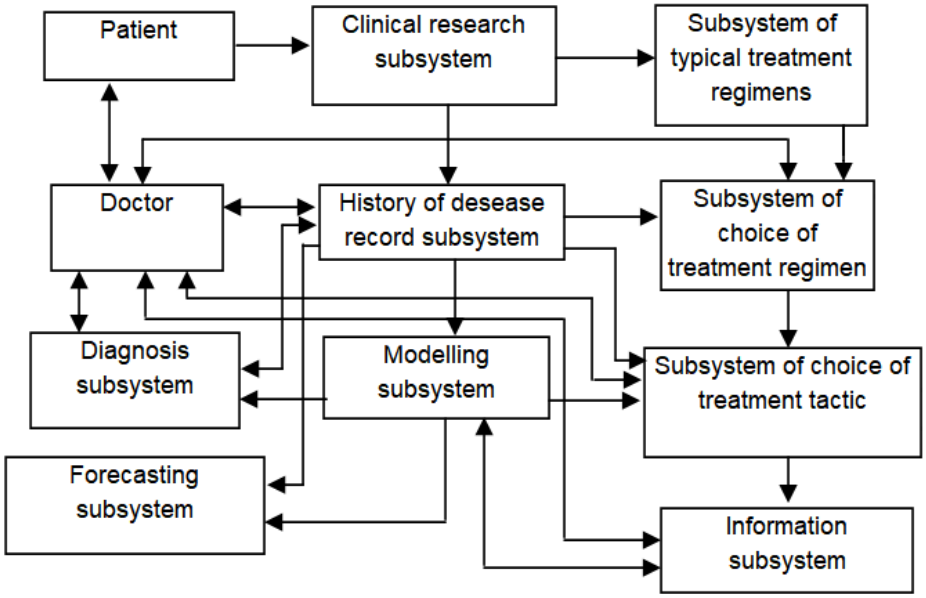

Fig. 4. Infological scheme of the automated workplace of the neurologist

In the process of certification, AWP receives a comprehensive assessment, defined as the arithmetic average of three group coefficients namely: assessment at technical level (K_1), assessment at organizational level (K_2), and assessment at the level of working conditions and safety (K_3). Each of these levels, in turn, is also defined as the arithmetic average of the estimates for each of the elements (criteria) that make up this level. According to the results of AWP certification, each workplace should be assigned to one of three categories: certified, conditionally certified, not certified. Schematically, the work on optimization and certification of automated doctor's workplaces can be represented by the scheme shown in Fig. 5.

The generalized results of certification allow to obtain systematic information about using doctors' AWP in any clinical or sanatorium structure in order to optimize their structure, functional and operational capabilities.

7 Experiments and results

Achieving an optimal level of health care is possible basing on an integral information technology for managing the treatment and diagnostic process, which includes the planning, motivation and control, diagnosis, rehabilitation, and developmental sequence according to present-day medical standards.

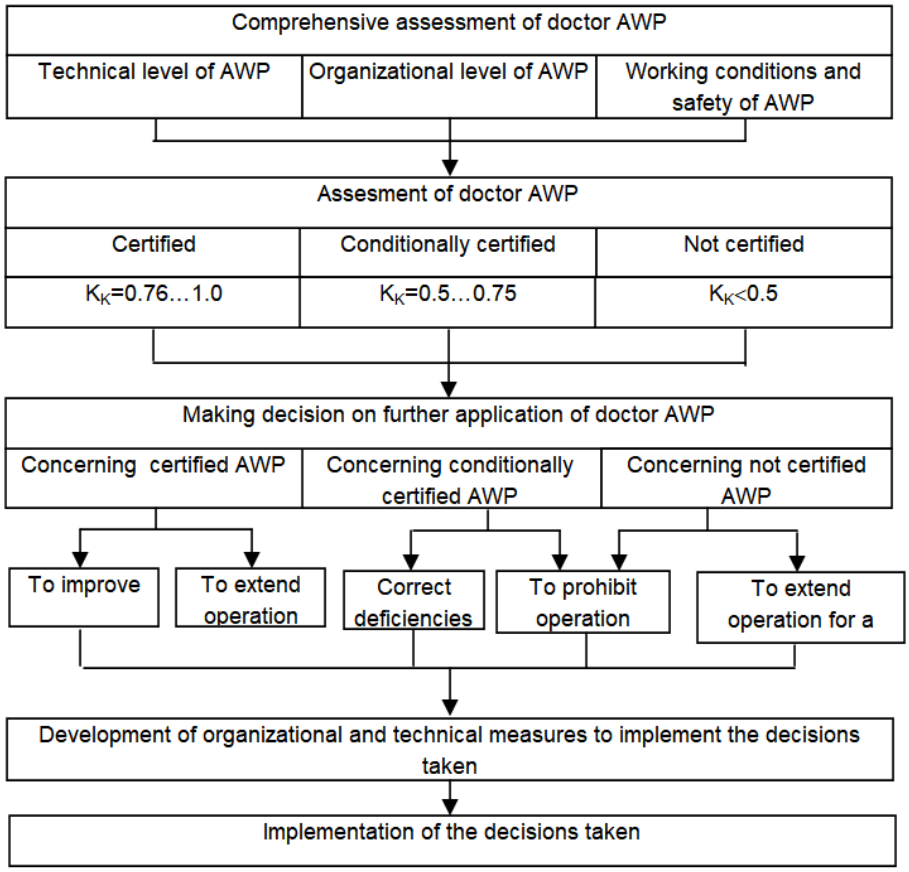

Fig. 5. Scheme of optimization and certification of doctor's automated workplace

One approach to rise an effectiveness of treatment and rehabilitation procedure (TRP) is applying the method of sequential comparison using standard estimates. According to this method, the efficiency is determined by expertly calculating the values of individual indicators according to groups of criteria and measuring their relative significance using an interval scale. At the first stage, the organizational system of TRP is identified basing on the goals, functions and resources of this system. The second stage is the formation of performance criteria. The final procedure for the formation of a system of criteria is their ranking by the degree of influence on the efficiency of TRP [21]. The ranking is carried out on a quantitative scale in the range from 0 to 10. The maximum rating is assigned to the indicator having the greatest advantage. If the expert's mark of the i-th attribute is designated as a_{ij}, then the relative weight of the indicator (V_i) can be calculated using the formula:

$$V_i = \frac{\sum_i a_{ij}}{\sum_i \sum_j a_{ij}} \quad (1)$$

The indicator having the greatest weight gets rank 1.0. For each of the most important criteria, a utility scale is developed with the range from 0 to 1.0. The main purpose of the scale is to convert dissimilar gauges to their equivalent points. An example of constructing such a scale is presented in Figure 6.

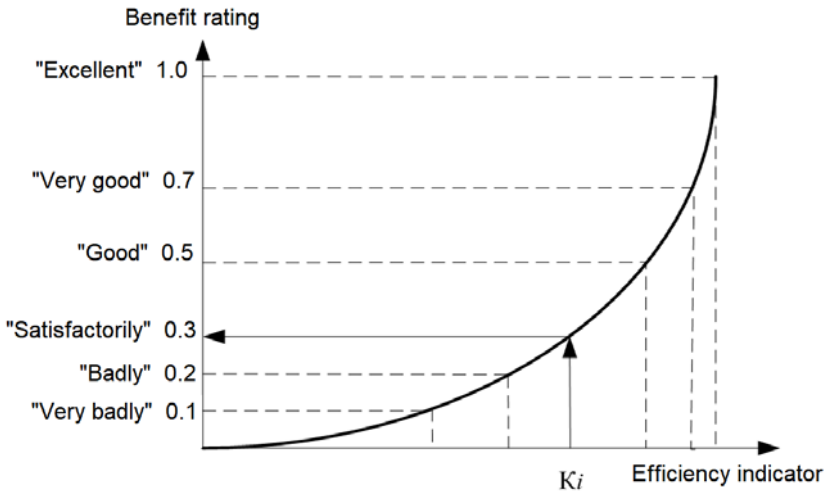

Fig. 6. The scale of utility for assessing the effectiveness of TRP

The third stage includes the calculation of the actual values of the indicators and the conversion of the obtained numerical estimates into points using the utility scale.

The fourth stage is the analysis of the effectiveness of TRP organization. This stage includes the calculation of reserves of efficiency and the relative assessment of the significance of the criteria for improving the effectiveness of the system. Standardized indicators and normalized assessments are used to assess the effectiveness (E) of the treatment or rehabilitation as:

$$E = \frac{A_{br} - A_{ar}}{A_{br}} \cdot 100\ \% \quad (2)$$

where A_{br} and A_{ar} are the assessment of the state before and after rehabilitation, respectively.

MIS was probated upon pilot project conducted in sanatorium “Metallurgist” in city of Mariupol. The project allowed to compare the sanatorium activity indicators as a result of MIS application. The effectiveness of medical information system was studied through an anonymous survey of the users (47 people in total). Twenty nine persons of them were the doctors, the rest were employees and nursing staff. The

persons who had previous computer experience were: doctors (72 %), employees (29 %), nursing staff (38 %). The duration of work with the system ranged from 10 to 18 months, while almost half of the users worked with MIS throughout the entire period.

Analysis showed (Fig. 7) that MIS implementation led to significant improvement of all the considered indicators.

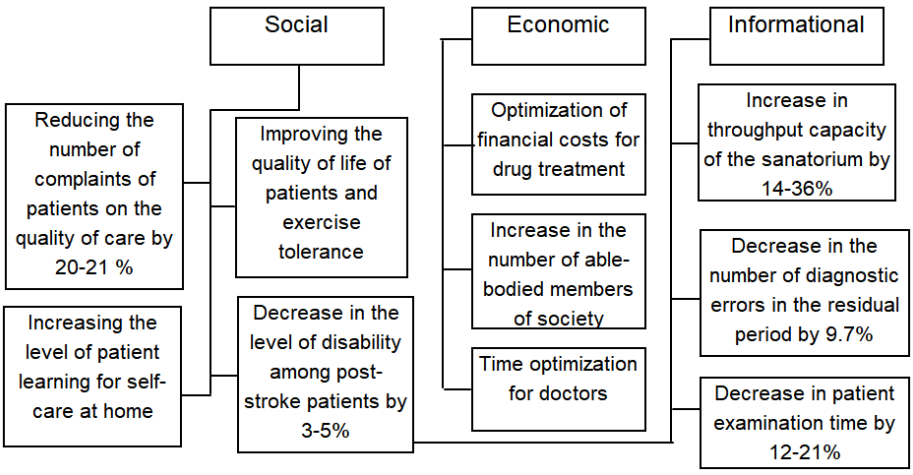

Fig. 7. The results of MIS usage in practice

Specifically, the doctors' time decreased: for the doctor core work - by 25 %, for paperwork - by 33 %, for patient examination - by 12-21 %. The number of patients served during the same time increased by 14-36 %. The number of complaints for the quality of medical care decreased by 20-21 %; the number of medical errors decreased by 9.7 %. The time spent by the doctors for professional development in relation to the total working time increased by 15 %.

If the overall assessment of the rehabilitation treatment is rated as: 1 - excellent, 2 - good, 3 - poor, then the analysis showed the following. The doctors evaluated rehabilitation treatment without MIS as 1.9 and with MIS as 1.0. The patients evaluated rehabilitation treatment without MIS as 1.7 and with MIS as 1.1. This reflects the improvement of rehabilitation strategy and treatment measures.

The presented results show the high effectiveness of developed medical information system.

8 Conclusion

The analysis of the existing approaches of information support for the rehabilitation treatment of post-stroke patients allowed to set the measures aimed at minimizing the risks of complications of the central and peripheral nervous systems. It also resulted

in development of criteria and principles for more effective information support. Some of these principles and criteria allowed to substantiate the strategy of managing the residual period of rehabilitation of post-stroke patients. The concept of monitoring the state of post-stroke patients and principles for ensuring the continuity of rehabilitation measures using medical information system were formulated.

A medical information system for the rehabilitation of post-stroke patients was developed in this work. The system is based on structuring each of the levels according to relevant criteria, which allows to take into account the effect of endogenous and exogenous risks.

Two-step control of medical appointments was implemented based on information model of the rehabilitation system, providing an automated control of appointments and procedures for compliance with the diagnosis with further adjusting the rehabilitation procedures. This resulted in decreasing the number of prescribing drugs and therapeutic procedures which were inadequate to the state of the patients.

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