Personalized medicine software solutions

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Abstract. The article examines the example of the implementation of the telemedicine information system – "Medical information system of accompanying chronic diseases therapy". Based on the current monitoring of blood pressure, heart rate, and antihypertensive therapy prescribed by the doctor. The concept of developing MIS meets the paradigm of modern medicine, supporting the concept of personification, prediction, prevention, patient involvement in the treatment process based on a positive approach to therapy for patients with hypertension. Formal approaches to automatic correction of therapy based on the method of tree solutions are considered.

1. Introduction
The introduction of telemedicine into the practice of health care allows to fully realize the concept of concern for the health of citizens – "Citizen Healthcare", according to which each person should receive the entire amount of medical care (preventive, emergency, planned, etc.) through electronic health systems in the place where it is now [1].

Telemedicine projects have become possible thanks to modern technologies for storing, processing, transmitting, and presenting data, such as cloud technologies, mobile technologies and wireless data transmission, interaction through medical information systems.

Widespread development has been the systems of remote fixation and transmission of physiological parameters with the help of various devices connected with a computer or digital mobile devices, gadgets.

The use of remote fixation and transfer systems of physiological parameters, observation and control, teleconsultations of the patients allowed to transfer outpatient medicine to a qualitatively new level, making available round-the-clock medical consultations, life-long preventive measures, long-term monitoring, and emergency corrections of the key parameters of life of patients [2].

In the context of modern and perspective technological possibilities, medicine develops in accordance with the paradigm of proactive medicine 5P: personal, predictive, preventive, positive medicine, precision medicine [3].

The development of information systems that fit the paradigm of modern high-tech medicine requires the software engineers to combine different technologies, methods and means of implementation in the context of the achieved goal.

The article describes the technologies and methods of automation of the therapy of chronic diseases in the context of the paradigm of modern medicine on the example of the medical information system of accompanying chronic diseases therapy, the work on which was carried out by a team of authors [4].

A feature of the system being developed is its orientation for the treatment of arterial hypertension in combination with the conduct of therapy under the supervision of a doctor with the help of the MIS.
Algorithm of work is determined by the medical protocol’s treatment of arterial hypertension, and monitoring of the patient’s condition and control of the arterial hypertension is carried out by the module of automatic therapy. Decision-making to change therapy, organized in accordance with the doctor’s decision, is complemented by a decision obtained based on a binary decision tree that takes into account all possible outcomes of changing therapy depending on a set of values for patient monitoring parameters, including blood pressure control, patient compliance indicators, quality of life parameters and other characteristics that influence the choice of treatment options.

We are present the scientific community to the results the implementation of our medical system, to discuss the main results of its application in medical practice, to discuss of decision-making models.

2. Materials and methods

2.1. Description of the medical information system for the maintenance of chronic diseases therapy

The medical information system is implemented based on web technologies in close cooperation with cardiologists of the Voronezh Regional Cardiology Dispensary. The purpose of the MIS is to provide information to patients, to monitor the physiological parameters of the patient in the mode of remote transmission and data-fixing. The therapy includes the use of prescribed drugs during of the period of 26 or 52 days. Clinical indicators contain the results of blood pressure measurements, heart rate, assessment of the patient's compliance [5], and the quality of life [6].

The concept of a personalized approach to the MIS is implemented by the following: it’s determines the method of remote interaction, chooses an individual regimen to control arterial hypertension (AG) considering all clinical data on the patient. All the ways in which the patient, the doctor and the MIS interact is demonstrated on the figure 1.

![Figure 1. MIS – ways to interact.](image)

The client part of MIS is implemented in the form of a web-based application.

For the first version of the system, the method of remote interaction was possible in one variant, namely: the patient has a phone with a function of SMS-information, the doctor registers the patient's phone number, selects the feature send SMS with the need to measure pressure, drugs at the appointed time. The first version of the system did not meet the requirements of the 5P paradigm and was then modified. Two more ways of interacting have been developed to complement the patient's involvement in the therapy process:

1. The patient has a smartphone based on OS Android. In this case, the patient before the mobile application - a subsystem of mobile interaction within the framework of the MIS. Interaction with the patient is carried out through reminders of the need to measure pressure and take the drug in, the response the patient sends, taking advantage of the possibility of the graphic UI of the mobile attachment [7].
2. The patient has a blood pressure monitor with a GSM module. In this case, the patient can also receive a text alert or reminder via a mobile app, but the blood pressure readings and heart rate are added to the database immediately after the pressure measurement.

The patient's involvement in the treatment process is marked by reminders of the need for pressure measurement and taking drugs using SMS-alert or notifications in a mobile app.

After receiving a notification, the patient measures the pressure. Measurements are entered by the patient in the form of digital values in the input field and after clicking on the "Send" button, are transferred to the server, or stored locally on the phone if there is no communication.

In the mobile application, it is assumed that after some time from issuing a message about the need to take the drug, in the absence of confirmation from the user, the message is re-generated. All these actions are repeated for each scheduled appointment. After the last time you take the drug, the app contacts the server to check changes in the scheme the next day, as well as form other mandatory messages for the patient (figure 2).

If you do not have an internet connection, the data is stored in the phone and the data will be sent as soon as you connect to the Internet. Until the messages are sent, the user will see a sign (yellow questioner, which will warn that the data has not yet been sent).

Thus, the mobile application provides the organization of interaction and monitoring of the patient's condition through our system as a client-application of the patient of MIS.

The function of assessing the positive concept of the paradigm 5P is implemented using with the mobile application. To assess the psycho-emotional state of the patient and his compliance with the dynamic therapy, it is provided to send the value of the quality-of-life status in the form of an emoji.

The value of quality-of-life on a scale from -2 to 2 is fixed in the database. The doctor may decide on the need for close contact with the patient, contact with him on the phone, contact the patient's confidant or change the therapy ahead of schedule. The predictive function in the MIS is realized at the level of creation of the algorithm of automatic therapy [8].

![Figure 2. A common approach to setting checkpoints.](image)

The diagram shows checkpoints that have the following designations:

- **V** - face-to-face (first, control, etc.) patient's visit to the doctor and the entry of data into the MIS.
- **V+1** is the next day after a visit to the doctor, when the patient begins to take the prescribed drug and receive reminders about the measurement of blood pressure and taking drugs.
- **K** is a control point that determines the recurring time interval in the days from the date of the beginning of (changes) of therapy.
- **K-N** is a control period for calculating set values.

When the control occurs, the MIS performs all scheduled automatic actions.

If the control period is set to determine any indicators, it will be considered a priority for the MIS, even if the reminders of the measurement of blood pressure or taking drugs on these days do not send to the patient.

In order to implement the above-mentioned algorithm, the MIS realized the possibility of choosing an automatic therapy regimen and the possibility of setting parameters for changing therapy on the results of the assessment of the state of health on the control date.

2.2. Technology and methods of automation of treatment correction

Consider the formal approaches used in the MIS for automatic arterial hypertension therapy based on data from monitoring the condition of the patient and blood pressure control.
The automatic therapy module's algorithm is subject to the logic of the code and the rules for the organization of arterial pressure monitoring, monitoring of the patient’s health (figure 3).

Figure 3. The algorithm of the automatic therapy.
The algorithm of the therapy assumes a strict sequence of actions. The interface of the MIS doctor is organized so that the doctor consistently went through all stages of the organization of patient therapy to ensure the conditions of monitoring:

1. Writing data on blood pressure measurement conditions, reminder parameters, safety parameters (critical blood pressure parameters) in relation to the patient.
2. Determining parameters of automatic therapy (figure 2).
3. Prescribing of drugs in the frame of the created regimen of automatic therapy with the name, form, dose of drugs, time of admission, re-notification of the need for admission.

   All data are stored in the database.
4. The work on the interaction between MIS and patient continues with the Cron (Linux operating system service), daemon is run in the background based on specially designed scripts, providing reminders to patients in accordance with the parameters of automatic therapy.
5. The script provides receipt and retention in the database of messages from patients, blood pressure monitors, mobile application.
6. Analysis of the results of monitoring provide a module of the automatic therapy.
7. Based on the analysis of the results of automatic therapy, the patient receives recommendations: parameters of the patient's notification about the end of the therapy (achieved referential readings of SYS, DIA and pulse, the end of therapy, the recommendation of the doctor, continue therapy with the use of parameters of change in therapy, recommendations on lifestyle changes, improvement of quality of life, real visit to the doctor).

3. Formal methods of decision-making for treatment correction

Various approaches, such as fuzzy logic, prediction logic was considered to choose the method of decision, but doctors, operating within the treatment protocol, required automata approaches to the organization of the choice of treatment change decision. The authors suggested using a decision tree [9, 10, 11].

Formally describe the decision tree can be using a formula.

$\{x,Y\} = \{x_1, x_2, x_k, Y\}$ (1)

The dependent variable, $Y$, is the target variable.

The vector $X$ is composed of the values key model parameters $x_i$ such as the average blood pressure parameters over the period of analysis; average quality of life over the period of analysis; patient compliance rate for the monitoring period; the number of representative blood pressure measurements during the analysis period.

To choose an option, value must match set of values:

$x_1 = mean(P_{sys}, P_{dia}, P_{pulse})$,

$x_2 = mean(P_q)$,  \hspace{1cm} (2)

$x_3 = P_{copl}$,  \hspace{1cm} (3)

$x_4 = P_{real}/P_{vol}$,  \hspace{1cm} (4)

where $P_{sys}$ and $P_{dia}$—blood pressure values.

$P_{pulse}$—heart rate values.

$P_q$—indicator of quality of life.

$P_{real}$—number of real blood pressure measurements.

$P_{vol}$—number of expected blood pressure measurements.

In accordance with the method of building a decision tree, you need to set the solution node and specify alternative outcomes.

A binary tree was built for our example.
Table 1 provides a classification of outcomes for a tree with result identifiers. The classification is stored in the database. For each variant there are options for alerts, system events and users.

**Table 1.** Decision outcomes.

| ID  | Outcomes                                                                 |
|-----|--------------------------------------------------------------------------|
| id1 | Continue therapy. Patient alert. Recommendations.                       |
| id2 | Continue therapy, call the doctor to the patient.                       |
| id3 | A visit to the doctor. Patient alert.                                   |
| id4 | Leave therapy unchanged. Patient alert.                                 |
| id5 | Automatic change of therapy according to the treatment plan. Patient alert. |
| id6 | Doctor's alert.                                                          |
| id7 | Control of blood pressure and doctor's consultation on the phone.        |
| id8 | Control of blood pressure without therapy. Patient alert.                |
| id9 | Control of blood pressure without therapy. Doctor's consultation.        |
| id10| Stopping monitoring. Visit to the doctor.                               |
| id11| Automatic disabling of the therapy regime with the patient's alert.      |
| id12| Manual disabling of the patient's activity regime.                       |
| id13| A visit to the doctor. Patient alert.                                   |
| id14| Contingencies. Manual disabling patient activity.                        |
| id15| Automatic change of therapy according to the treatment plan. Warning to the doctor about the patient's low compliate. A doctor's call to the patient. |

Table 2 presents the keys to the solution tree nodes.

**Table 2.** Keys are nodes of the decision tree.

| Node key | Decision tree node name                                                                 |
|----------|----------------------------------------------------------------------------------------|
| 01       | Continued therapy.                                                                      |
| 02       | End of therapy.                                                                        |
| 011      | There is enough data for analysis. Over the monitoring period, more than 80 per cent of the projected data was collected. For example, during the 7-day analysis period, blood pressure is monitored 21 times. More than 15 measurements must be taken. |
| 012      | Data for analysis is not enough.                                                        |
| 0111     | Reference values have not been achieved.                                               |
| 0112     | Reference values have been achieved.                                                    |
| 01111    | There is no change in therapy.                                                         |
| 011111   | Unsatisfactory quality of life.                                                        |
| 011112   | Satisfactory quality of life.                                                          |
| 0111121  | Trends are positive. Analysis of the trend of blood pressure measurements for the entire period of therapy. |
| 0111122  | Trends are negative. Analysis of the trend of blood pressure measurements for the entire period of therapy. |
| 01112    | Changing therapy is envisaged.                                                         |
| 03       | High compliance.                                                                       |
| 04       | Low compliance.                                                                        |
| 021      | Forced end of therapy.                                                                 |
| 022      | Non-forced end of therapy.                                                             |
| 0211     | According to the doctor's decision.                                                    |
By patient's decision.

At the end of the automatic therapy regimen, indicating the need to visit a doctor.

Outside of the end of automatic therapy.

The decision tree is depicted in figure 4.

Thus, the binary tree includes all the situations of therapy and develops a control decision on further change of therapy, monitoring the patient's values with informing the doctor and the patient about the nature of the changes.

The combination of medical treatment protocols with the ability to monitor patients' condition and control physiological parameters has given the instrumental means of accompanying the therapy of arterial hypertension, that is different from the current medical solutions.
4. Results and discussions
Assessment of the quality and effectiveness of automated maintenance of hypertension therapy and decision to change therapy we leave to cardiologists and in this article do not consider.

Let us look at the results of the presented solutions from an information and technology point of view. For a sample of 50 patients who received the service of treatment with the help of MIS, 24 people used the mode of interaction with SMS, 18 people used whether the mobile app and 8 people had a blood pressure monitor with the function of automatic from the correction of pressure data and used a mobile app to monitor with GSM. Figure 5 shows a diagram of the quality of maintenance therapy with the help of MIS, assessed the convenience of interaction.

![Figure 5. Assessment of the quality of accompanying therapy (patient survey).](attachment:image.png)

According to the patients themselves, the most convenient way to accompany the disease was a mobile application, with which they can send all the data on health and blood pressure control parameters. All patients using the mobile app reached the end of the therapy with the reference values and showed a high degree of involvement in the therapy process. The use of blood pressure monitor with the GSM module was assessed ambiguously because the inconvenience is that it is necessary to connect the blood pressure monitor to the electrical network and wait for 3–5 minutes to send data to the server and get confirmation of the success of data retention. For patients who using phones with SMS function – the accompaniment was inconvenient, 8 people early dropped out of the project of their own accord. Thus, it was decided to further develop the system and develop a mobile application for all kinds of mobile operating systems.

5. Conclusion
International studies of telemedicine use within the 5P paradigm point to the following positive trends in the treatment of various diseases:
- Significant reduction in hospitalizations and hospital stays.
- Patients are better "understood their disease" because they are involved in process treatment.
• Improved quality of care, timely correction of drug therapy led to high effectiveness of drug treatment.
• The positive impact of telemonitoring on the quality of life, psychological and social condition of the patient is assessed.

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