Methods and technologies for increasing the energy efficiency of portable medical devices

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Abstract: The role of portable medical devices in modern medicine is increasingly increasing. One of their main problems is the limited energy supply and low energy efficiency. The study studied methods and technologies for increasing the energy efficiency of portable medical devices. 120 portable medical devices used in medical institutions of Uzbekistan were analyzed. A special microcontroller system and artificial intelligence algorithms were developed to reduce energy consumption. As a result, the energy consumption of the devices decreased by an average of 35%, and the service life increased by 1.8 times. The introduction of the created technologies into clinical practice made it possible to significantly increase the efficiency of portable medical devices.

Keywords: portable medical devices, energy efficiency, microcontroller, artificial intelligence, energy saving

INTRODUCTION

In an era of rapid development of modern medicine, the importance of portable medical devices is increasing. These devices significantly expand the possibilities of monitoring the health of patients, conducting diagnostics and providing emergency medical care. Especially during the COVID-19 pandemic, the role of portable medical devices has become even more evident.

However, there are a number of problems with the widespread use of portable medical devices, the most urgent of which is the limited power supply and low energy efficiency. This problem is especially important in cases requiring long and continuous monitoring, in remote areas and in emergency situations.

In recent years, large-scale work has been carried out in Uzbekistan to digitize the healthcare system and introduce modern medical technologies. The development of portable medical devices and increasing their efficiency has been identified as one of the priority areas within the framework of the "Digital Uzbekistan" strategy for 2022-2026.The problem of increasing the energy efficiency of portable medical devices requires an integrated approach. In this process, the use of modern microcontrollers, energy-saving technologies and artificial intelligence algorithms is

of great importance. At the same time, reducing energy consumption while maintaining the reliability and accuracy of medical devices is an important task.

The purpose of this study is to develop methods for increasing the energy efficiency of portable medical devices and evaluate their effectiveness. During the study, the following tasks were solved:

- Analysis of energy consumption of existing portable medical devices
- Development of an energy-saving microcontroller system
- Creation of energy management algorithms based on artificial intelligence
- Conducting clinical trials of the developed technologies

MATERIALS AND METHODS

This study was conducted during 2021-2024. As part of the study, 120 portable medical devices used in leading medical institutions of the republic were studied. Among them, there were 45 portable ECG monitors, 35 portable pulse oximeters, 20 portable ultrasound devices and 20 portable ventilators, and their energy consumption, operating time and efficiency indicators were analyzed in depth[2-3].

A special system based on a modern ARM Cortex-M4F microcontroller was developed to optimize the energy consumption of devices. This system includes advanced technologies such as dynamic frequency control, multi-stage sleep modes and Smart Battery Management System. A distinctive feature of the microcontroller system is the automatic optimization of energy consumption depending on the device’s workload in real time.

An innovative aspect of the study is the development and implementation of special artificial intelligence algorithms for energy consumption management. These algorithms based on Deep Learning technologies allow for the prediction of the device's operating mode and the optimization of energy supply accordingly. The algorithm creates an adaptive control system taking into account the device's previous operating history, user habits, and environmental conditions.

The tests were conducted in three stages. In the first stage, the energy consumption of existing portable medical devices was thoroughly analyzed and technical requirements were developed. In the second stage, a microcontroller system and artificial intelligence algorithms were implemented and preliminary tests were conducted. In the final stage, the modified devices were tested in clinical conditions.

All obtained data were statistically processed in the IBM SPSS Statistics 26.0 program. Differences between groups were assessed using the Student t-test and the Mann-Whitney U-test. The value of $P<0.05$ was considered statistically significant. Energy efficiency was assessed by indicators such as device operating time, energy consumption (mW/h), battery power conservation, and stability of operating parameters.

Modified versions of portable medical devices were tested by the Uzbekistan Agency for Standardization, Metrology and Certification and received appropriate certificates. All tests were conducted in accordance with the requirements of the international standard ISO 13485:2016. The results of the study were approved by the Ethics Committee under the Ministry of Innovative Development of the Republic of Uzbekistan.

RESULTS AND DISCUSSION

Increasing the energy efficiency of portable medical devices is one of the pressing problems in modern medicine. The results of the study showed that the integrated use of energy-efficient microcontroller systems and artificial intelligence algorithms can be an effective solution to this problem.

Preliminary analyses showed that there are a number of serious problems in the operation of portable medical devices. It was found that in 65% of the 120 devices studied, the battery power is completely consumed during one work shift. This directly affects the quality of medical care. The fact that the devices require an average of 4-5 hours to fully charge was also assessed as one of the factors hindering their effective operation.

A distinctive feature of the developed microcontroller system is its dynamic frequency control and the presence of multi-stage sleep modes. The system automatically optimizes energy consumption depending on the device load. The Smart Battery Management System technology allows for the most efficient use of battery resources. As a result of the implementation of these technologies, the continuous operation time of the devices increased by 1.8 times, and the average energy consumption decreased by 35%.

The use of artificial intelligence algorithms led to even more significant results. Algorithms based on Deep Learning technologies analyzed the history of the device's previous operation and allowed it to optimize energy consumption in real time. The accuracy of energy consumption prediction reached 92 percent, and unexpected energy losses decreased by 85 percent. The algorithm created an adaptive control system taking into account user habits and environmental conditions.

Clinical tests of the improved devices showed particularly noteworthy results. The signal quality of ECG monitors maintained 98.5 percent accuracy, the measurement error of pulse oximeters did not exceed 0.5 percent. The image quality of ultrasound devices showed 96 percent accuracy, and the stability of ventilators was 99.2 percent. These indicators confirm that the reduction in energy consumption does not negatively affect diagnostic accuracy.

The battery life has improved to 70 percent, and the full charge time has been reduced to 2.5 hours. These changes have made it possible to increase the efficiency of medical personnel and ensure the continuity of patient monitoring. The importance

of these technologies has become especially evident in remote areas and in emergency situations.

The significance of the results of statistical analysis ($p<0.001$) confirms the high efficiency of the developed technologies. It was found that all indicators of the devices used in clinical practice fully meet the requirements of international standards. This determines the prospects for the widespread introduction of these technologies[3].

The results of the study showed that there are opportunities to increase the energy efficiency of portable medical devices. The developed technologies allow not only to reduce energy consumption, but also to ensure the stability of the operation of the devices and diagnostic accuracy. This is of great importance for improving the quality of medical services and reducing costs.

CONCLUSION AND PRACTICAL RECOMMENDATIONS

The results of the research on increasing the energy efficiency of portable medical devices made it possible to find a solution to one of the most pressing problems of modern medicine. The developed energy-efficient microcontroller system and the integrated use of artificial intelligence algorithms significantly increased the efficiency of portable medical devices.

The results of the study showed that the combined use of modern microcontroller technologies and artificial intelligence algorithms allows reducing the energy consumption of portable medical devices by 35 percent and increasing their service life by 1.8 times. This is especially important in cases requiring long and continuous monitoring, in remote areas and in emergency situations.

The introduction of artificial intelligence technologies made it possible to optimize energy consumption in real time. The use of Deep Learning algorithms made it possible to predict energy consumption with 92 percent accuracy and create an adaptive control system depending on the operating mode of the device. This made it possible to reduce unexpected energy losses by 85 percent.

The results obtained during clinical trials confirmed the high efficiency of the developed technologies. The signal quality of ECG monitors maintained 98.5 percent accuracy, the measurement error of pulse oximeters did not exceed 0.5 percent, the image quality of ultrasound devices showed 96 percent accuracy, and the stability of ventilators was 99.2 percent - this proves that these technologies do not negatively affect diagnostic accuracy.

Improving the battery life by up to 70 percent and reducing the full charge time to 2.5 hours will increase the efficiency of medical personnel and ensure the continuity of patient monitoring. This is of great importance for improving the quality of medical care and reducing costs.

Based on the results obtained, the following practical recommendations were developed:

It is necessary to widely introduce the developed energy-saving technologies in medical institutions of Uzbekistan. This process should be carried out gradually and take into account the specific characteristics of each institution. It is advisable to organize special training programs for medical personnel during the introduction of technologies.

It is recommended to develop a special program for the use of energy-efficient technologies at local enterprises producing portable medical devices. This program should be developed taking into account the requirements of international standards and regularly updated.

The creation and implementation of a system for monitoring the energy efficiency of portable medical devices is of great importance. This system will allow for real-time monitoring of the efficiency of devices and timely identification of problems.

It is necessary to expand international cooperation in the development of energy-efficient technologies. It is advisable to develop international scientific and technical cooperation programs to study best practices in this area and master new technologies.

As a final conclusion, it can be noted that the technologies developed to increase the energy efficiency of portable medical devices allow not only to reduce energy consumption, but also to improve the quality of medical services and reduce costs. This will serve as an important step in the development of modern medicine.

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