Healthcare in the digital age. A short survey.

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***Abstract*— The main objective of this study is to provide a brief overview of the methods for monitoring the health of the body in the light of modern advances in electronics, computer technology and communication solutions. Several types of sensors for recording biomedical signals are reviewed. An overview of some modern technological solutions for registration and processing of biomedical signals such as smart watches, bracelets and specialized devices for monitoring the health status of patients in home conditions was made.**

***Keywords*— ECG, PPG, spo2, healthcare, embedded systems, biomedical signals, communications**

I. INTRODUCTION

The classic interaction between a doctor and a patient in the time before the COVID-19 pandemic took place with minor differences as follows: when a person needs health care, he goes to his GP, makes a date and time. On the appointed date he goes for an examination. The doctor appoints tests, if necessary, prescribes certain therapy and drugs, and the patient begins to fulfill the prescriptions. During and after the pandemic, there have been "small" changes and it is no longer impossible to carry out an examination "over the phone", to prescribe drugs "over the phone", etc. In addition to changes in health care, there have also been changes in the relationship between different entities, such as the use of remote work, learning had become almost every day [1][2]. The purpose of this article is to provide a brief overview of the technologies, devices, communication solutions enabling these new ways of doctor-patient connection to become a reality.

II. TECHNOLOGY

The appearance and development of the mentioned changes is due to the development of technologies in the field of communications, microelectronics and software.

Table 1 lists some of the existing technological solutions used in modern healthcare. Some of them was used from years, some are emerging. For example, AI has been developing at a great speed in recent years, but so far there is no information that a standard has been created by which it can be used to make diagnoses.

TABLE I. TECHNOLOGIES

Type	Function
Medical databases	Easier monitoring of patient's condition
Medication prescription	Reducing medication prescribing errors
Remote monitoring	Obtain current patient status remotely
Telemedcine	Observe patients' status by phone, video or other remote method
AI	Use AI to help of decision make

1. Centralized databases – the digitization of patient data improves overall patient care. Test results, prescribed medications, examination results, diagnoses and any other data regarding the patient's health are just a key press or a mouse click away.

2. Electronic prescriptions – Unlike the classic paper prescription, it minimizes the occurrence of errors. It allows prescribing the necessary drugs when needed remotely. Limiting the possibility of "self-medication", especially with antibiotics.

3. Remote monitoring - Timely detection of potential disorders in the health condition leads to faster initiation of appropriate treatment for the patient. On the other hand, with some types of diseases, it is necessary to monitor the patient's condition for a longer period of time - for example, when examining the work of the heart.

4. Telemedicine - Especially important in remote regions without a constant medical presence. In our country and around the world there are remote areas without a constant presence of medical personnel. Telemedicine allows people in these areas to receive adequate medical care.

5. AI – Its use in medicine cannot go unmentioned. It is especially suitable to be used where it is necessary to process a large volume of data, processing specific research results, etc.[3]

Last, but not least, the use of technological advances in addition to the conveniences assured, they also save money. If the patient can "save" the visit to the doctor, he saves transportation costs, time, wages. The doctor, on the other hand, also saves on transportation costs, and the time he saved can be used to see and help other patients.

III. DEVICES

Remote patient monitoring is changing healthcare by allowing healthcare professionals to monitor patients outside of conventional clinical settings. This leads to improved monitoring of chronic diseases and improves the quality of patient care. This applies to the greatest extent to patients located in remote areas or encountering difficulties in getting to health facilities. Medical devices collect a wide range of health data such as blood pressure, vital signs, glucose, weight, blood oxygen levels and heart rate, and electronically transmit this information to healthcare professionals for

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evaluation. By using these devices, healthcare professionals can closely monitor patient health trends.

Table 2 shows some of the most common smart medical devices.

TABLE II. MEDICAL DEVICES

Type	Size
ECG monitors	Miniature/Small
Pulse and SPO_2 meters	Miniature/Small
Wearables	Miniature/Small
Glucose monitors	Miniature/Small
Robots	Micro/Miniature/Small/Large
Smart scales	Small
Blood Pressure	Small

1. ECG monitors - they are indispensable in patients with heart diseases. Particularly useful ECGs are Holter devices, allowing the recording of heart activity for a longer period, for example 1-2 days. In some cases, the monitoring can be even up to a month or more, as then it is not constant, but is carried out according to a certain scheme.
2. Pulse and SPO_2 meters – Pulse oximeters are relatively simple devices for measuring the oxygen content of the blood. They are useful in patients with respiratory diseases or other diseases affecting the functioning of the lungs. By placing a finger or other accessible place, the oxygen content can be monitored over a long period of time and different actions can be taken accordingly.
3. Wearables - Wearable devices are the backbone of remote health monitoring. Usually, these devices are in the form of bracelets or watches. In other cases, they are a separate device attached to a part of the body. The parameters they measure include movement, activities, sleep. In patients with diabetes, they can record glucose levels. In patients with heart disease, atypical heartbeats are recorded. Another application of such devices is in studying the state of athletes during training, the state of the body during extreme loads and the like.
4. Glucose monitors - They allow measuring the glucose levels in the blood according to a certain scheme. In this way, the need to visit a health facility is eliminated. When very low or very high values of glucose levels detected, the patient and the attending physician can be notified. After processing the obtained data for a longer period, certain dependencies in the state of can be detected to help appoint a more appropriate therapy.
5. Robots – There are different types of medical robots. Some of them are used in surgery like da Vinci Surgical System [5], others are used to help people with difficulty moving. Others are used to disinfect the premises in health facilities[6]. Another type of medical robot system is the Cyberknife[7] used to radiation treat of tumors.
6. Smart scales - Smart scales are used by patients with heart failure, diabetes or obesity. The obtained data is sent to the attending physician to improve diets, change the diet or perform certain exercises. In addition to weight, smart scales can calculate and track body fat percentage and body mass index (BMI)
7. Blood pressure - Blood pressure measurement is of great importance for patients with hypertension or cardiovascular disease. The received measurement data is sent to a database for processing, tracking changes. In this way, a more detailed picture of the changes in the blood pressure is obtained, which in turn gives the necessary information to medical personnel to select an appropriate therapy for treatment.

IV. RISKS

Usage of digital devices into medicine, in addition to positive effects for the health of patients and the new opportunities which it provides, also brings some risks. Some of them are presented below [2][4]. Others that do not currently exists may arise as the use of smart medical devices and software programs expands:

- Reliability – even with the best designed devices there is a possibility of failure during operation.
- Security – most important for devices that are connected to the Internet constantly. The greater their number, the greater the probability that one or another device will be compromised.
- Systems failure – interruption of the power supply, failure of infrastructure components such as servers, network devices, etc.
- Problems in the simultaneous operation of different devices and systems – usually occur when implementing a new system or updating a working one. Everything is installed, checked, but it turns out that there are problems in communication between the new and existing technology. In some cases, manual data transfer between the two systems is reached, which is time-consuming.
- Lack of rules – even with the latest and most efficient devices and systems there is a high probability that they will not be used effectively and for their intended purpose if there is absence of clear and easy to understand and implement rules and regulations.

V. SENSORS

To be able to register biomedical signals, medical devices use sensors that convert the given value (eg temperature) into an electrical signal that can be processed and digitized. In this way, the data for the studied parameter can be recorded, archived and saved for comparison. Some of the most common types of sensors for recording biomedical signals will be reviewed below:

1. Temperature – in the past mercury thermometers were used to measure body temperature. Despite their great accuracy, their use is decreasing, and somewhere they are prohibited for sale due to the presence of mercury in them. Modern digital devices use semiconductor sensors [10][11] that are

calibrated to operate in a narrow range of temperatures, usually around normal human body temperature.

2. ECG - It is a recording of the heart's electrical activity. For the recording, electrodes placed in certain places on the body are used. The potential difference between them is considered. There are various specialized integrated circuits for primary processing of received signals such as [12][13].
3. SPO_2 - An optical method is used to measure the oxygen saturation in the blood. It is based on the ability of substances to absorb part of the light passing through them. When light passes through a blood vessel depending on the oxygen content there is a different absorption. Two light sources of red and infrared color are used. Oxygen-rich blood absorbs more infrared light and less red, while oxygen-poor blood absorbs more red light and less infrared. On this basis, after mathematical processing, the oxygen content in the blood is determined. There are two main types of sensors for determining SPO_2 - one works on the principle of light passing through the organ - most often a finger or ear, the other uses the principle of reflection - they are used, for example, in wrist smart watches, fitness bracelets and the others similar.
4. Glucose monitors - Blood glucose monitoring can be done in two ways - constantly and when needed. Here we will look at how continuous reporting of glucose level. It uses a glucose sensor that is placed under the skin, usually on your stomach or arm. It is sticked so that it does not move. This type of sensors are disposable. The other type of sensor is implanted in the patient's body. Both types of sensors determine the amount of sugar in the fluid between cells, which is coresponding to the amount of sugar in the blood vessels. Sensors have a certain life and must be replaced when it expires. The data received from the sensor is transmitted wirelessly to a receiver or insulin pump. The use of a specific type of sensor is determined by the attending physician.

VI. COMMUNICATIONS

Table 3 shows a several communication technologies used by a medical devices.

TABLE III. COMMUNICATION TECHNOLOGIES

Type	Power	Link length	Speed	Price
Bluetooth	Low	Short	Low	Low
WiFi	Medium	Medium	Medium	Low
Cellular	High	Long	Medium	Medium
Wired	High/Very high	Short	High	High
Satellite	High	Long	Low/Medium	High
NFC	Low/Very low	Very low	Very low	Low

As can be seen from the table, different communication technologies have different parameters, and this determines which of them should be chosen for a specific case.

Below is an attempt at a brief overview of each:

1. Bluetooth - Bluetooth - there are several standards, the maximum speed of volume between devices is of the order of 1-3Mbps. The maximum connection distance is up to 1000m (BT5LE) outdoors. In a room it is much smaller and depends on the ability of radio waves to pass through the walls, ceiling and floor of the room. A big advantage is relatively low energy consumption.[8]
2. WiFi - Depending on the standard, the speed between individual nodes can be from 11Mbps(801.11a) to 9.6Gbps(802.11ax). The distance between individual devices can be up to 1000m outdoors and up to 500m indoors depending on the standard used. Power consumption is relatively high. When used indoors there is degradation of WiFi traffic if there is many devices working.
3. Cellular - Mobile networks provide relatively large coverage at a relatively low cost. There are currently active networks of all generations from 2G to 5G around the world, as the latter provide the greatest capabilities. According to the technology of their construction, they provide connection speed between devices from several tens of Kbps (GSM 2G, 3G) to several hundreds of Mbps (5G).
4. Wired – They used as a medium twisted pair cable, optical cables, coaxial cables etc. The main advantage of using a such type of cables are very high speed between devices. There is no problem to have a speed of 10Gbps between two devices at a very reasonable price. The limiting factor is the size of cables.
5. Satellite - Satellite communications have no alternative in places where there are no mobile or terrestrial networks. Depending on the service provider, speeds of up to several hundred mbps are achievable. A disadvantage is that the equipment for making the connection has a relatively high power consumption.
6. NFC – As the acronym says it is Near Field Communication. So, it can be used for communications between devices which are at several centimeters distance. The main advantage of this type of communication is very low power consumption.

CONCLUSIONS

Digitalization is having a significant impact on healthcare. By digitizing the health records, a better awareness of the history of the patient's diseases is achieved and hence for an easier and faster determination of the diagnosis of the disease, as well as for a more accurate determination of the appropriate treatment.

Another advantage is the use of modern telemedicine tools that allow patients to consult with medical professionals from a distance, reducing the need for in-person visits and

increasing access to patient care in remote or underserved patient's areas.

The use of big data and machine learning allowed improved analysis of large numbers of patients information leading to the identification of patterns and trends which can inform the development of more effective treatments.

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