Innovations in the Management System of the Process of Taking Medicines by Patients Based on Digitalization

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In modern conditions, the digitalization of the healthcare sector has increased the pace of development. This is due to the peculiarities of the development of the COVID-19 pandemic and the need to solve issues related to public health more quickly than in the pre-pandemic era.
Today, digital healthcare platforms for diagnosis and monitoring of treatment, patient adherence and tracking of medicinal products are new scientific fields. However, innovative technologies and digital solutions are currently not available to all residents of our country, this is due to the ability to access the Internet, the provision of potential patients with PCs and phones with access to the Global Network. Nevertheless, the introduction of these technologies even in the most remote corners of various countries of the world is necessary, since the constant wave-like development of

morbidity indicates a long-term prognosis of the spread of coronavirus infection. Accordingly, people must learn to live and fight this disease, and information technologies in the field of medicine can help them in this. The purpose of the work is to consider innovations in the management system of the process of taking medicines by patients based on digitalization.

1. INTRODUCTION

Modern society is increasingly digitized and depends on the virtual world and a huge amount of data. This is changing the process of developing products and delivering them to customers - an example of this is the recent revolution in value creation and consumer demand due to the COVID-19 pandemic, which has become a significant development incentive for e-business. This development partly depends on the effective use of online services and traceability of products.

Recently, one of the key tasks has been the distribution of pharmaceutical products. At the same time, it was necessary to quickly solve a number of tasks:

- providing solutions that allow you to personalize medicine;
- organization of the fight against counterfeit and counterfeit products;
- reduction of the environmental impact of the relevant production.

One of the solutions to this problem is the integration of data elements into medicines. This will simultaneously ensure the safe provision of medicines to patients, more accurate and timely dosing of drugs, as well as tracking the volume of consumption of a particular drug. Thus, conventional medicines can turn into digitized products [1].

In turn, this can help healthcare professionals make an informed decision about subsequent treatment options, which will ultimately lead to a better therapeutic outcome. In addition, the traceability aspect of digitized medicines will contribute to a more efficient pharmaceutical supply chain (PSC), facilitating new strategies for reducing medical waste, developing more sustainable products, and finally integrating PSC with elements of a closed economy. In addition, these digitized medicines should be functional and at the same time accessible and for use in low- and middle-income countries.

2. MATERIALS AND METHODS

In the article, comparative research methods were used to analyze the material, the study of the issue was carried out on the basis of data obtained from their sources found on the topic of the study.

3. RESULTS

The digitalization of the healthcare sector is proceeding rapidly due to the gradual integration of diagnostic sensors in places of medical care. Currently, personal mobile and wearable sensors, the so-called Internet of Things (IoT), can measure, among other things, functioning, breathing, sweat biomarkers and even assess a person's emotional state [2]. Transmitted signals from the IoT can be received, quantified and visualized using, for example, a standard smartphone. These digital capabilities make it possible to create a completely new type of human-machine interface in the healthcare sector. Already, there are more and more digital solutions that provide virtual visits to doctors based on communication between the patient and the doctor based on applications [3]. Even clinical trials are becoming more and more virtual. In this digital revolution, the weakest link in the chain is the medicinal product. This is due to the fact that the possibilities of its tracking, dose testing and integration into existing digital healthcare platforms are limited. In order to be able to provide truly personalized care, holistic changes in the healthcare sector are needed, and a key element of this change will be the way to develop an individual drug intake system (IDIS). The current model of mass production of medicines does not allow for personalization, while product modification based on the genome, metabolism and activity level of an individual patient requires the implementation of the principles of mass customization [4].

The current organization of conventional pharmaceutical production is based on the mass production of selected dosages. This creates problems, especially in the treatment of chronic diseases, including cardiovascular diseases, type

2 diabetes, as well as brain diseases. Many methods of treating the disease require the administration of several doses to the patient, depending on the severity of the disease, lifestyle changes, simultaneous administration of other medications, as well as discontinuation of medication. In addition, different subgroups of patients will require age-appropriate doses. In this regard, there are three main problems currently existing in the field of medication administration:

1. lack of personalization and accuracy of drug dosing (especially for children);
2. uncontrolled intake of various groups of drugs (age group of the population);
3. lack of easily accessible specialized information about medicines [5].

Most pediatric medicines are liquid preparations supplied in measuring cups or in the form of a teaspoon or tablespoon. In the case of solid dosage forms, the available doses are divided, for example, by crushing or dividing into halves or smaller, and then consumed in kind or by dispersing in oral fluids. These are not very accurate measurement systems and they are very susceptible to the effects of human error. In addition, the age, weight and metabolic capabilities of children can be decisive factors in determining the correct dose.

The importance of the correct dose for use in pediatrics is often reflected in market reviews related to the need for accurate dosing. Such a recall is burdensome and expensive and can lead to a loss of confidence in the recalling company [6]. Recently, the attention of pediatric medicines has been attracted by dosage forms in the form of minitablets and granules. Minitablets are miniature tablets that can be counted to get the necessary dose. They are suitable even for newborns. However, it is necessary to use a separate device that allows you to accurately count the minitablets, for example, a specially designed pen. This increases the cost of the drug. In addition, although the production of minitablets is well established, this is due to various technical problems, including the uniformity of the contents, as well as the maintenance and mechanical stability of punches with multiple tips. Also, due to their small size, minitablets are not easy to handle on their own, which can create additional problems for patients with impaired motor functions and geriatric patients. Granules in solid capsules or sachets for pediatric use have also been developed to improve the intake of the required dose.

It is assumed that the desired number of granules should be distributed by parents or guardians in semi-solid food, such as apple pudding, yogurt or fruit juice, so that children eat the medicine unnoticed and thereby minimize spilling, spitting out and refusing to take the medicine. However, this approach may cause additional problems with insufficient medication intake due to, for example, the child's unwillingness to take the entire portion of food, as well as additional requirements for the stability of active pharmaceutical ingredients (API) and other ingredients in the presence of food [7].

Polypharmacy, patient morbidity and poor adherence to the treatment regimen are the main factors contributing to the suboptimal outcome of drug administration systems in the elderly. Poor adherence to medications is caused, among other things, by the inability of patients to recognize their medication due to a similar appearance, forgetting or misunderstanding of the intake regimen, unwillingness to comply with a complex dosing regimen or difficulty swallowing. A key challenge in developing appropriate drug administration systems for the elderly is to provide innovations that best meet the specific physiological, psychological and multiple drug needs of individual elderly patients. While digital literacy may be a problem for elderly patients, caregivers in nursing homes may be well trained in the use of digital media. In addition, the population aged 50 to 60 years, who are doing well at their age, is already well acquainted with the digital world.

4. DISCUSSION

Thanks to the digital revolution, patients have become more informed than before. Millions of questions related to taking medications are entered into search engines every day. Various studies have shown that more and more people are looking for their medications and related information on the Internet. In addition, people find it useful to check the origin of raw materials and their logistics, especially if patients have allergies or concerns about trust. This aspect will become increasingly important when pharmaceutical products and the logistics supply chain of medicines are modified towards more sustainable solutions with elements of a closed-loop economy.

For example, a pharmacist may receive unused traceable medications from patients without the original packaging. The information embedded in these tracked medications at the dosage unit level can help pharmacists sort them by dose, expiration date, etc. for reuse or recycling.

In order to overcome the problems associated with currently sold medicines, innovative solutions with improved functionality are needed. One of such innovations is personalized drug intake system (IDIS) - solid dosage forms containing an individualized exact dose of one or more active substances for the patient and having an individualized appearance that can help in identifying, ingesting, releasing and monitoring the effect of drugs [8]. Additive manufacturing (AM), based on various methods of two-dimensional (2D) and three-dimensional (3D) printing, has recently emerged as a new technology for IDIS due to its universal capabilities of producing variable doses on request. With the use of AM, the dose can be adjusted digitally, by rapid manipulation in the computer-aided design (CAD) system of the dosage form to be printed [9].

Reducing the number of dosage forms that need to be consumed per day could significantly improve patient adherence to treatment and provide cost savings for the health sector. One of the first products in this field is a 3D-printed product developed by Aprecia - Spritam® (Keppra® generic drug product) containing levetiracetam against epilepsy, it was approved by the US Food and Drug Administration (FDA) in 2015 [10]. This product has the advantage of a mouth-dispersible formulation in terms of ease of ingestion, combined with the possibility of digitally adjusting the dose on request [11]. Thus, the IDIS can allow the production of medicines at the request of patients in an industrial environment. These opportunities will allow to modernize the existing supply chain of medicines and will require its revision.

The pharmaceutical supply chain (PSC) is quite complex and has special characteristics that are not usually found in the supply chains of other consumer goods. These special characteristics include the need for higher security, full traceability, and secure storage of records, especially if the records contain sensitive information.

The researchers note the complex nature of the traditional PSC model and the involvement of multiple stakeholders. It includes the flow of raw materials to pharmaceutical manufacturers, followed by the flow of finished pharmaceutical products through a chain of wholesalers and distributors, retailers and, ultimately, to end users (patients and medical professionals) [12]. There are various risks associated with the traditional PSC model, such as drug shortages; impaired PSC resistance, counterfeit medicines (fake medicines imitating real medicines) and counterfeit (medicines that do not comply with intellectual property rights or violate trademark law) and expired goods (resale of expired products).

The recent COVID-19 pandemic crisis has forced the society of pharmacists to reconsider a number of established technologies. First, contingency plans should be prepared to avoid a shortage of medicines. In addition, repurposing existing drugs for new therapeutic indications could reduce drug shortages when specific treatments are not yet available.

Currently, the volume of drug production is calculated based on the expected consumption of drugs, and not the actual needs of patients. This is one of the reasons for the accumulation of huge pharmaceutical waste, for the disposal of which additional resources are required. This situation is due to the fact that the traditional PSC is basically a linear chain working on the concepts of acceptance, manufacture, use and disposal. The complete digitalization of the PSC, even with a single intake, is tracked in a digital system and will provide a better overview of manufactured, consumed and unused or expired medicines. This, together with the real needs of patients, will create the basis for mass customization options. In addition, a Circular Pharmaceutical Supply Chain (CPSC) has been proposed as a future strategy to support sustainability in the pharmaceutical sector to reduce, among other things, drug shortages and their accumulation. There are already several innovative examples in PSC, where the basic principle of the 3R circular economy (reduction, reuse, reuse) is implemented. Major initiatives have been proposed for implementation, such as pharmaceutical drug return programs to implement mainly the principles of "reuse" and "recycling" in PSC [13]. CPSC is a further extension of the 3R principle to the 9R model, which includes recycling, reinvention, reduction, reuse, repair, restoration, repurposing, recycling and restoration to further optimize the closed-loop economy. 9R can make a significant

contribution to the achievement of the United Nations Sustainable Development Goals through three main strategies:

1. improving the process of using products and production by eliminating the use of less environmentally friendly materials, rethinking the intensive use of certain products and reducing the consumption of natural resources by increasing production efficiency;
2. extending the life cycle of a product by reusing a discarded product that is still in good condition, or by repairing, restoring or restoring an old product;
3. the search for a useful use of the product by repurposing the product for another function, or by recycling to achieve better quality, or by restoring energy from burning used material. The 9R model has not yet been fully implemented to create a more sustainable pharmaceutical and healthcare sector [14].

Also, the spread of counterfeit medicines, both counterfeit and counterfeit, should be avoided, as it has become a serious threat worldwide, especially in developing countries such as Africa, Asia and Latin America, where the presence of counterfeit medicines is higher and even cases of deaths due to substandard medicines have been reported. This has also proved to be a huge problem for developed countries, especially in a pandemic situation such as COVID-19. To minimize the risk of fraud, pharmaceutical companies develop a unique shape, color, size, impression, impression, etc. d. both the dosage form and packaging to assist in the identification and authentication of the medicinal product outside the production unit. Therefore, increasing transparency for end users will be important, especially if medicines are distributed directly to patients, bypassing the participation of a pharmacy acting as a guarantor of quality control and a provider of consulting services.

The shortage of medicines, the proliferation of substandard medicines, the impossibility of instant authentication and the inability to track the drug, as well as the desire of society for more accessible information and sustainable solutions are pushing regulators and researchers to develop this area. IDIS and digital health are currently developing rapidly in parallel directions, but they can complement each other. For example, the same QR code can be used both to track a batch of medicines and to accumulate the

necessary information for both patients and medical professionals. Thus, the integration of these areas can lead to progress in health systems, provide cost-effective treatment solutions, and improve overall health outcomes.

In order to get an overall picture of people's health status with the highest possible accuracy, technologies for automatic, minimally intrusive monitoring, tracking and continuous assessment of human behavior and context are emerging. This has become possible due to the wide availability of personal computers and devices and communication services, including personal wearable devices, as well as mobile applications and services. Such devices and services collect several types of high-resolution data (for example, location, physical activity) longitudinally and imperceptibly. They also provide the user with some type of data visualization.

The researchers note the development and application of 438 types of body-worn sensors associated with various behaviors. The network of devices and services that evaluate a given behavior is the Internet of Things (IoT). Simultaneous collection and analysis of several responses can, for example, give a better picture of the severity of the disease and help in choosing the right treatment [15].

In addition, the Internet of Things can be used in case of non-compliance with the medication regimen, for example, due to the fact that elderly people forget to take medications. In general, non-compliance with the treatment regime is a huge problem in the field of healthcare. To improve compliance with the treatment regimen, intelligent drug containers have been developed that detect the opening of a pack of medicines or the use of containers with liquid medicines.

The potential of technologies using IoT is broader and may include technologies that track behavior and individual states associated with adherence to treatment or with a therapeutic outcome (for example, pain relief) due to medication. If we look specifically at IoT technologies embodied in wearable devices, that is, on an individual body, they can track sleep, physical activity, food intake, pressure, etc. To date, almost none of the wearable devices are used to track medication intake, although almost all of them can be used for these purposes. Many of these Internet of Things technologies can be very personalized. Personalization can include functions ranging from simple fixed, time-

based reminders, through the management of a complex medication schedule (including changing the intake schedule in case of missed doses), to timely context-dependent systems that, for example, recognize that a person has just woken up or is currently eating, remind them to take a certain type of medication. Developers and providers of devices and services are making more and more efforts to make them accessible, user-friendly and useful, including for people with lower digital literacy.

The use of personal and mobile devices, such as smartphones, has demonstrated a huge potential for the development of healthcare, including the prevention and treatment of diseases. Over the past decade, 85% of mobile phone users in Europe and the United States have had smartphones. The smartphone, its sensors and related mobile applications can be used as a tool to collect high-quality data for medical research or regular medical practice, since data can be collected unnoticed for long periods of time, in the laboratory, as well as in the natural environment of the facility.

A smartphone can also become a "treatment adherence sensor" - either acting as a reminder or interaction service to take medication or avoid double intake, or relying on smartphone sensors - to quantify a person's conditions and behavior related to compliance with a treatment regimen, or to track symptoms (or lack thereof) in a person's daily life. It is also used as a processing and display tool with the possibility of using it to track medication intake, decide on a treatment plan, potential correction of the drug administration regimen, etc.

5. CONCLUSION

In general, there are many human factors that are associated with the development and use of IDIS and can affect the results of patient treatment. For maximum patient acceptance, any choice of IDIS design should be easily personalized to match the patient's existing daily routine and lifestyle. For example, for medications taken after waking up or during meals, the interactive design (that is, the number of interactive steps to activate the system or the size of the system to be placed in the patient's office or on the breakfast table) of the IDIS should correspond to the patient's morning routine or meal schedule. In general, the results of previous studies show that design elements and personalization options for a system such as

IDIS should be implemented in such a way that users feel good. There is a growing demand in society for therapy adapted to an individual approach to the patient in order to improve the overall result of treatment and increase overall profitability. Personalized drug delivery systems offer an innovative digital solution that can overcome the problems associated with currently sold medicines, in particular, they can provide personalized and accurate doses on request, dosage form, improve adherence to treatment and give a better overview of treatment, provide the ability to track and verify the authenticity of the drug by including unique identifiers.

In addition, IDIS can become a link between the pharmaceutical and digital world, as the healthcare sector is increasingly digitalized with the invention of a completely new type of treatment, such as digital therapy. However, in order to make the general concept of IDIS workable and sustainable, it is necessary to solve the relevant technological, economic problems, as well as problems of confidentiality and data security, and also take into account the relevant human factors.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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