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SELECTED APPLICATIONS OF IT TECHNOLOGIES SUPPORTING NURSING AND MEDICAL CARE

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ABSTRACT

The COVID-19 pandemic related events taking place in years 2019-2021 exposed numerous gripes afflicting healthcare systems, while at the same time accentuating issues which were previously well known and marginalized. Simultaneously, the same occurrences resulted in forced and rapid shifts of many sectors of the economy towards remote work. In the United States, an estimated number of remote working employees during the pandemic exceeded 50%, while before Covid-19 emerged, it had been below 15%, which testifies to the existence of technical and infrastructure resources, indispensable to the computerization of the economy (Brynjolfsson et al, 2020). However, this is not a universal capability, as there are entire branches of industry and services requiring direct involvement of employees, including i.a. the strategic sector (e.g. the energy sector), industry in the broad sense of the word, or public services (infrastructure maintenance, healthcare etc). In this group, the healthcare system is in a special position, since not only are the healthcare workers at risk of coming into contact with pathogens, due to no possibility of remote based work, but they also engage in efforts to combat the effects of the epidemic among the general public. Despite differences existing among workers, based on their role in the system (f.e. between a general practitioner and hospital employees), immunizing the healthcare system against perturbations in its functionality, is the key task in the context of society as a whole.

Keywords: nursing, biomedical engineering, medical systems

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1. Introduction

The COVID-19 pandemic related events taking place in years 2019-2021 exposed numerous gripes afflicting healthcare systems, while at the same time accentuating issues which were previously well known and marginalized. Simultaneously, the same occurrences resulted in forced and rapid shifts of many sectors of the economy towards remote work. In the United States, an estimated number of remote working employees during the pandemic exceeded 50%, while before Covid-19 emerged, it had been below 15%, which testifies to the existence of technical and infrastructure resources, indispensable to the computerization of the economy [1]. However, this is not a universal capability, as there are entire branches of industry and services requiring direct involvement of employees, including i.a. the strategic sector (e.g. the energy sector), industry in the broad sense of the word, or public services (infrastructure maintenance, healthcare etc). In this group, the healthcare system is in a special position, since not only are the healthcare workers at risk of coming into contact with pathogens, due to no possibility of remote based work, but they also
engage in efforts to combat the effects of the epidemic among the general public. Despite differences existing among workers, based on their role in the system (f.e. between a general practitioner and hospital employees), immunizing the healthcare system against perturbations in its functionality, is the key task in the context of society as a whole.

2. Analysis of the efficiency aspect of the Health Care system condition

The Act of March 2, 2020 vested almost unrestricted management in such places as hospitals with the government
administration which was intended to simplify the redistribution of resources in the healthcare system and maximize the systems efficiency [2]. It needs to be noted that despite the said efforts, the health care system was hurled to the edge of its efficiency a few times, which was partially caused by years of negligence and idiosyncratic characteristics of healthcare in Poland.[3]

Despite the high number of the available hospital beds in Poland (Fig. 1), placing it among countries with the biggest buffer in a range of inpatient healthcare capacity, a

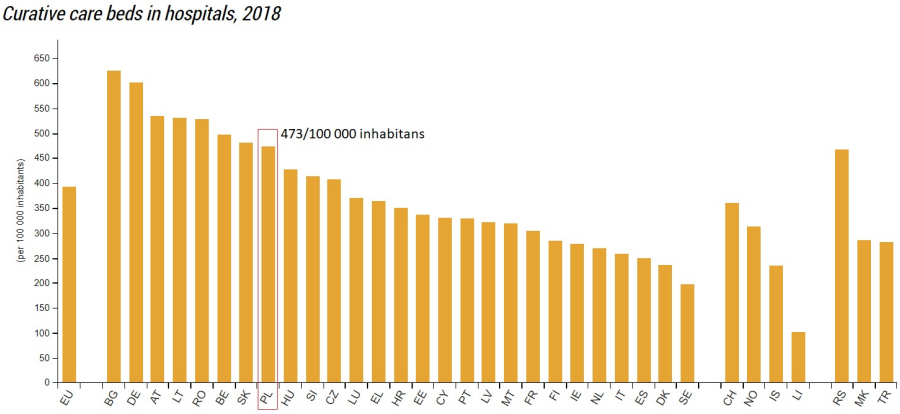

Figure 1. Availability of hospital beds per 100 000 residents in European countries in 2018 (according to Eurostat) [4]

significant shortage of the processing capacity in diagnostic and treatment fields occurred during the COVID-19 pandemic.

simultaneous reduction of the personnel's engagement in sectors that would not result in the patient's well being being negativel

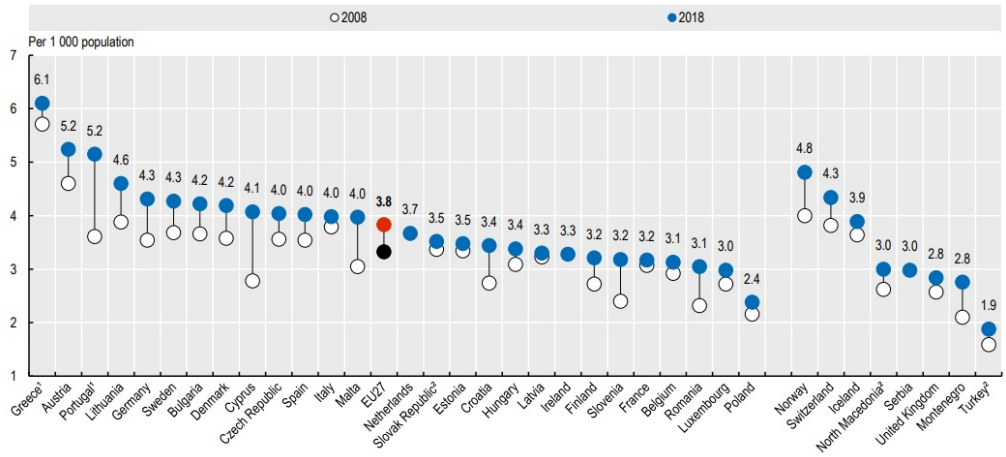

Figure 2. Professionally active doctors per 1000 residents in European countries in 2018 (according to OECD) [5]

One of the main reasons for such shortage is incommensurability of the available medical personnel in relation to the available utilities and infrastructure. According to an OECD report from 2020, there are only 2.4 doctors per 1000 residents in Poland, which is an indicator significantly diverging from other countries of the European Union (Fig. 2). A similar situation is associated with the availability of nursing care, as in this case, the rate of the available nurses per 1000 residents is almost threefold lesser than in f.e. Finland (Fig. 3).

3. Advances of computerization techniques and automation in the context of clinical nursing care issues

The occurrence of deficits in the nursing personnel results in the necessity to optimize the deployment of the available active personnel, making it a matter of utmost importance. The key to fulfilling the said goal is to properly target efforts related to the performance of nursing duties, with

affected. Such measures should be supplemented by an analysis of the difficulties occurring in the performance of duties, difficulties which might not only result in the personnel's ineffective time management, but may also subject healthcare workers to psychological strain resulting in burnout. It is also worth noting that according to the research, nurses experience the highest job satisfaction in the aspect of social and personal value of their work. Therefore, focusing efforts on taking real action to elevate the quality of health care services should result in a corresponding increase in the job satisfaction as well as improvement in the work efficiency, and perhaps encourage young adepts to chose nursery as a possible career [6].

The main circumstances prompting impediments in the nursing personnel's performance of duties can be classified into three categories – pharmacotherapy, health state measurement and prevention of physical complaints. Issues of patient contact, nursing care of patients or preparation of treatment procedures have not been included, as these

are the essence of the profession, and in light of the presented research, the aspect of nursery providing high job satisfaction despite present complications.

the necessity of manually checking the condition of medications [7, 8]. This condition seems to be a good basis for the implementation of a complex IT system possibly

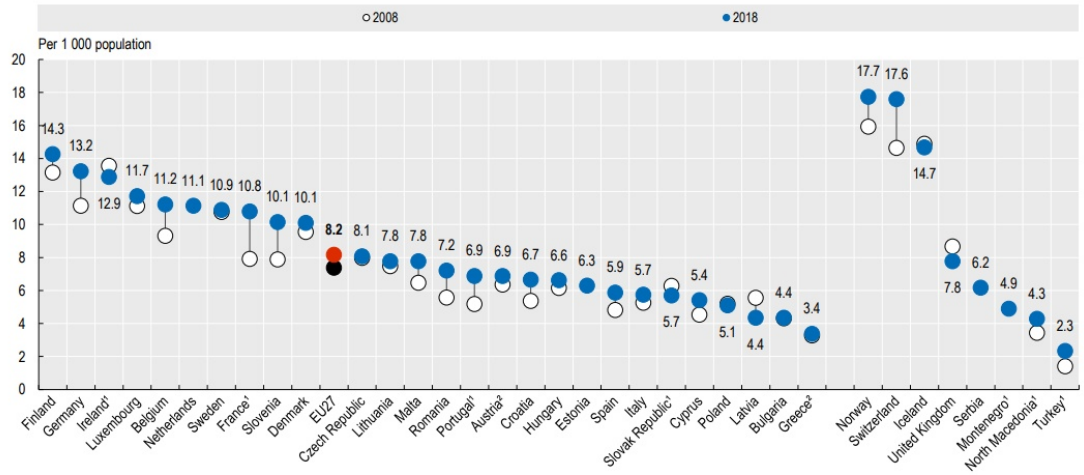

Figure 3. Professionally active nurses per 1000 residents in European countries in 2018 (according to OECD) [5]

3.1. Pharmacotherapy

75% of the treatment process steps within hospital pharmacotherapy are carried out by the nurse (reading and analysis of the instruction, preparation and administration of medications) while only 25% are handled by a doctor (prescribing). At the same time, steps carried out by a nurse are exposed to the occurrence of critical mistakes, f.e. caused by interruptions in the preparation process by emergencies for presence of a third party. Repeatedly, the personnel are faced with the low medical preparation availability, resulting in bizarre situations such as an unregistered flow of medicinal substances between hospital wards on the basis of a 'loan'. Moreover, the medication management system is in many aspects at its initial stages, or not instilled at all. In such a situation, the health care personnel not only is unable to see the full spectrum of possible pharmacotherapy implementations, but is additionally regularly burdened with responsibilities connected with stocktaking, and with a mechanical component (Fig. 4). Main tasks of such a software solution should be:

1. Supervision of the stock availability of medications with the established degree of detail (f.e. per hospital ward). Aside from reducing the the personnel's time, automated records enable the application of additional features:

a. notifications concerning depletion of the pre-expiration date of medicine resources;
b. the possibility of formalizing the existing procedures concerned with medicine fluctuation between hospital units;
c. supervision of the inflow and outflow of medicines of special consideration (f.e. morphine), which require distribution under reinforced monitoring, due to their addictive potential, etc.

2. Arrangement of a database for medicine substitutes – i.e. products with the same composition and a similar medicinal profile that

may differ from each other, f.e., by price. By providing an appropriate link of integration with commercial drug databases (f.e. Pharmindex), and an official list of medicinal products, it becomes possible to implement algorithms not only indicating the possible usage of the currently available medicine substitution, but also facilitating the procedure of ordering medication, optimizing the costs incurred by this procedure. Albeit, from the nursing personnel's point of view, the most important thing would be a feature, simple to use, involving an indication of the possible substitution for another, currently unavailable medication.

nurses in the process of dispensing drugs) and stationary (f.e. in the treatment room, on-call room etc.) would allow the information flow process automation. Additionally, it would be feasible to retrace a relevant drug-path and medical orders, which might be a significant aid in contentious issues. It is also possible to apply algorithms detecting f.e. likely drug-drug interactions, which is an additional factor ensuring patient safety and imposing medical order verification on the doctor, without having it done at the nursing personnel's expense. However, it does not exclude a countercheck by the personnel, as it could be simply achieved by employment of an interface feature allowing comments and feedback on medical orders.

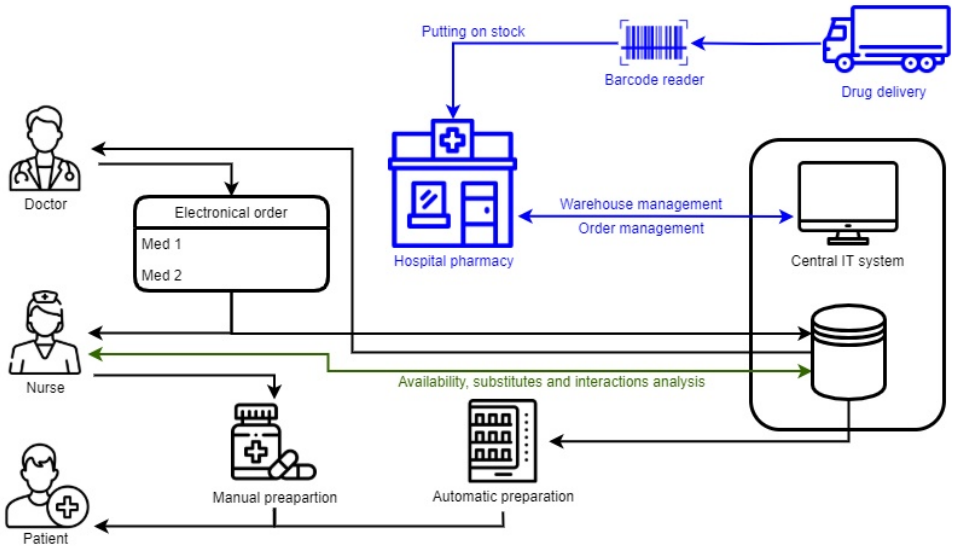

Figure 4. Framework of the proposed IT solution within the field of pharmacotherapy

3. Provision of simple interfaces for prescribing (doctor) and analysis (nurse) of an instruction within the scope of pharmacotherapy. Interfaces should be as simplified as possible, to avoid creating a high entry threshold for the personnel, such interfaces could match, f.e., the well-known and used medication orders card (prescription sheet). Implementation via mobile phones (for doctors during ward rounds, or

In case of application of additional hardware components, the possibilities are:

4. Implementation of a traceability class system, relying on bar codes of medicine packets, allowing control over the quantity of the dispensed medicine, but also the quality, f.e. inspection of expiration dates. Such systems not only encompass big solutions, f.e. in the food industry, they also became available for small

and medium companies in flexible and minimal configurations [9]. The scope of the achievable benefits is reliant on the deployment profile, as despite the automation of the process of reading and analysis (barcode scanners), it becomes necessary to insert information about expiration dates into the system at the time of receipt of products into the inventory.

5. Implementation of automated medicine distribution systems, which after integration with the program solutions will allow preparation of a set of medications based on electronic doctor's orders, which would reduce the necessary involvement of the nursing personnel to inspection of the medicine prior to dispensing and carrying out the dispensing process. Due to the costs of such solutions, as well as the proprietary software imposing the necessity of using the manufacturer's system, these systems would not be available for general hospital use in the foreseeable future. However, with the technological progress, this situation may change for the better.

Currently, systems of this type operate in a rudimentary form, usually covering only a certain range of functionality of the proposed solution. The standard is the Unit Dose system, enabling the transition from the distribution of full drug packages to the automatic supply of wards with individual doses for a given day. Importantly, as orders are carried out by the pharmacy and only distributed in the ward, there is a greater possibility of controlling, for example, interactions by the pharmacist, which is an important step towards ensuring greater safety of pharmacotherapy. Unfortunately, the implementation costs mean that despite the popularity in the United States (some form of this system is used in 97% of local hospitals), in Poland the solution is implemented only in the largest clinical units [10, 11]. Although the implementation of the Unit Dose system does not exhaust the assumed possibilities of computerization and automation, it is a significant step in the right direction by introducing drug dose labeling using universal technologies and standards, such as the GS1 barcode standard recommended by the European Association of Hospital Pharmacist [12]. In parallel, robotic systems are developed and implemented to physically distribute drugs into single-use, individual packaging - such as ABB's Robot Mini Load. Solutions of this type could ultimately become a component of the proposed system. The main obstacle in implementing such technologies is the price, which affects the availability of robotic systems only for the richest facilities [13].

3.2. Health state measurement

In the vital signs monitoring field, the main issue reported by the nursing personnel is connected with the existence of a dualism between the electronic system and traditional medical records done on paper. ICT supervision in the shape of a base station in an on-call room with equipment connected to it (f.e. cardiac monitor) is the commonly used surveillance tool for monitoring the patient's condition. However, often enough such resolutions do not allow on-demand examination with information transmission to a centralized database. This raises difficulties such as the necessity to put automatically taken measures onto the paper version of medical documentation. Using mobile based systems (also on tablets) by doctors, on the one hand, facilitates the work (lack of necessity of manual completion of documentation and orders), on the other hand, often requires electronic and on-paper documentation to be used in parallel, f.e. the patient's bedside card or on paper

documentation. A postulate submitted by the nursing personnel is mainly concerned with having electronic systems minimizing the mentioned dualism at disposal, and being characterized by high quality parameters in the area of UI/UX. This is linked to the rise of the average age of professionally active nurses, and the necessity of adjusting the ease of use to users with fewer digital competencies. The main tasks of a program solution should consist of:

1. Automatic download of results of measurements of vital signs from monitoring devices and aggregation in the context of each patient;
2. Sharing the current measurements and measurement history with the nursing personnel and doctors;
3. Automatic detection of life-threatening emergencies, and prompt notification of the personnel;
4. Facilitation of entering the descriptive parameters from the medical history. This quality involves the existence of intuitive and unequivocal evaluation systems, f.e. assessment of the pain intensity (using the adopted measuring scales);
5. Possibility of detecting potential threats f.e. for a patient with restricted mobility, the system should show a higher bedsore risk, which would expedite orientating multi-faceted nursing care;
6. Integration with other systems – the existence of many information systems results in further difficulties instead of a systematic resolution of the existing ones

3.3 Prevention of physical complaints

Prevention of afflictions among patients is a central point of nursing care and is based in its entirety on the personnel's knowledge and competence, with support of the technology and infrastructure. Frequently, the development of technical tools is gated by sectors, limited to enhancing measurements of biomedical signals or infrastructure upgrading. It seems as if contemporary manufacturing processes based on customer needs (in this case – medical personnel) were neglected, while the emphasis is placed on creating and meeting the needs of medical equipment manufacturers. It is an economically justified strategy, but it impedes potential innovations and grassroots inputs. The performed research revealed that the nursing personnel would welcome hardware and software innovations in fields such as:

1) Measuring and diagnostic systems supporting bedsore prevention in immobilized patients. The commercially available measuring solutions allow obtaining information about the pressure force with a high spatial and time resolution [14]. Integrating these solutions in the form of smart mats or mattresses, along with temperature and humidity sensors would allow automatic evaluation of the pressure distribution and skin parameters. In the long term, usage of commonly available tools and AI algorithms would enable predictions of dangerous situations, and thus support the personnel in bedsore prevention. Considering that bedsores are one of the most frequent problems in stationary healthcare, as well as problematic in treatment, prophylaxis of their formation could be a major factor in improving the quality of patient treatment and the work of the nursing personnel [15].
2) Systems of observation and analysis of behavior in patients with mental disorders. Detecting early stages of symptoms of possible disease exacerbation or emergence of characteristic behavioral patterns, enables early medical and nursing intervention, which reduces the risk of serious health consequences

and possible danger to the personnel. Account should be taken that the specificity of working at psychiatric wards requires a high level of interpersonal skills and involves the nursing personnel to a significant extent in duties requiring contact with the patient. Procedures of dealing with many afflictions demand accurate and adjusted presentation of the proceedings to the patient, maneuvering the conversation in a way that evokes appropriate emotions or expression of empathy towards the patient. Every hardware and software solutions relieving personnel from other duties or alleviating performance of such duties, are a substantial factor which might support treatment of patients with mental disorders [16]. At the same time, identification of hazardous situations (f.e. crowded room, possession of dangerous items) directly shields patients from harm and personal injuries, while also remaining in the field of possible usage of existing acquisition and image recognition systems.

3) Systems of environmental management in the patient's surroundings. Environmental sensors (air parameters measurement, dustiness, noise level, etc.) juxtaposed with simple analytical logic and performing devices, is in other uses a commonly encountered approach to providing comfort for persons occupying a room. In the case of special needs patients, f.e. with impaired thermoregulation, or with cardiovascular diseases, providing optimal environmental parameters could significantly reduce body strain, and be beneficial for recuperation.

The current process of computerization of the health care system in Poland is largely focused on the processes of information aggregation and data digitization. Examples include government initiatives in the form of the P1 (Electronic Platform for Collection, Analysis and Sharing of Digital Resources on Medical Events) and P2 (Platform for Medical Records) programs. Thanks to these systems, it is possible to have integrated access to information about medical entities or authorized medicinal products (P2), as well as integrated access to information related to the management of a personal treatment process - referrals, prescriptions, etc. (P1) [17,18]. In these areas, Polish electronic systems seem to be in the vanguard, not deviating from similar solutions introduced in recognized health care systems – i.e. Australian [19]. Due to their relatively wide scope and allowing the patient to view the history of treatment, as well as by allowing registration processes or documentation analysis to be performed remotely, these systems seem to be a good basis for connecting hospital systems. The solutions proposed by the authors result from the needs of the medical personnel in the facility, but undoubtedly a uniform, standardized and widely available system for collecting and analyzing data related to treatment enables the free flow of information between facilities and patients, eliminating the overhead of paper documentation. A common repository of this type of data is also important for public health, because even without access to detailed disease data, it enables the analysis of, for example, the development of epidemics of infectious diseases or the degree of burden on given medical entities, allowing the optimization of the entire system. Potential benefits may also be visible for patients - the register related to pharmacotherapy and hospitalizations allows an automatic analysis of possible side effects of therapy, taking the responsibility off the patient for the need to administer treatment side effects found in the past each time.

When analyzing both the existing and proposed solutions, it should be remembered that an important aspect often overlooked by nursing

personnel, linked with the implementation of this domain in the 21st century are inadequate digital competencies. It poses a significant challenge, as the simultaneous existence of numerous systems such as RIS or HIS in hospitals in connection with the rapid development of telemedicine might result in a multitude of tools incompatible with one another. Such an approach, instead of encouraging the use of IT created possibilities, might result in reluctance and apprehensiveness, thus contributing to a continuation of the present practices. Undoubtedly, the key issue is to provide complex patient and personnel service, which can be achieved by creation of software conglomerates (expensive and complicated), or creation of modular expansion of tools via standardization of communication and interface design principles. Despite the magnitude of such a challenge, it appears that even disobedience of these rules might still allow the IT industry to have a major role in the healthcare system, but without full realization of its potential.

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Conflicts of interests

The author(s) declare(s) that there is no conflict of interest.

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