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New technologies in health care — medical robotics and innovations during the COVID-19 pandemic, considering Polish achievements

Nowe technologie w opiece zdrowotnej — roboty medyczne i innowacje podczas pandemii COVID-19, ze szczególnym uwzględnieniem polskich osiągnięć

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Abstract

In March 2020, the WHO declared a state of a pandemic, which encompassed the whole world. During the pandemic, numerous new solutions have been introduced and some of the already existing ones have been improved to increase the safety, both of patients and healthcare professionals. The publication aims to present the achievements in the field of innovations with the effects of the Covid-19 pandemic, considering the activities of Polish scientists. The literature and current data were reviewed and useful in the topic of research were selected. The pandemic period showed the interdisciplinary nature of medical robots, both for surgical and diagnostic purposes. Robots are widely used in cleaning and disinfecting rooms. Patient psychological care systems also deserve attention - during the pandemic, the number of those in need suffering from mental diseases increased. Medical robotics should be developed and used more and more commonly.

Key words: COVID-19 pandemic, robot surgery, technological innovations

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Streszczenie

W marcu 2020 roku Światowa Organizacja Zdrowia (WHO) ogłosiła stan pandemii COVID-19, która wkrótce objęła cały świat. W czasie pandemii wprowadzono wiele nowych rozwiązań, a niektóre z już istniejących zostały udoskonalone w celu zwiększenia bezpieczeństwa zarówno pacjentów, jak i pracowników ochrony zdrowia. Celem publikacji jest przedstawienie osiągnięć w zakresie powstałych innowacji uwzględniających efekty pandemii COVID-19, z wyszczególnieniem działań polskich naukowców. Dokonano przeglądu literatury i aktualnych doniesień oraz wyselekcjonowano informacje przydatne w temacie badań. Okres pandemii pokazał interdyscyplinarny charakter robotów medycznych, zarówno do celów chirurgicznych, jak i diagnostycznych. Roboty są również szeroko stosowane w dezynfekcji pomieszczeń. Na uwagę zasługują również systemy opieki psychologicznej nad pacjentami — w czasie pandemii wzrosła liczba osób cierpiących na choroby psychiczne. Robotyka medyczna powinna być rozwijana i coraz powszechniej stosowana.

Słowa kluczowe: pandemia COVID-19, chirurgia robotyczna, innowacje technologiczne

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Introduction

The COVID-19 pandemic has killed up to this point over one million people all over the world (1 599 922 as of 15.12.2020) [1]. The virus was identified in December 2019 in Hubei, China [2]. A rapid dynamic of the infections, as well as the symptoms, which quickly lead to respiratory failure and, consequently, to death, caused the concern of the scientists given a high risk of infection. In March 2020, the WHO declared a state of a pandemic, which encompassed the whole world [3].

A clinical diagnosis of COVID-19 is made based on the symptoms, such as cough, progressive suffocation, fever, bad general sensation, loss of taste and smell. A molecular diagnosis is also essential. An extraordinarily useful tool is the imaging tests — computed tomography is considered a gold standard in the diagnosis of the illness caused by the SARS-CoV-19 virus [4–9].

An asymptomatic course of the illness is dangerous regarding its transmission and increasing range — a person who is unaware of the presence of the virus in his/her body can constitute an infection vector that spreads at a rapid pace, increasing the range of occurrence in a population [10–13]. As a result of quick transmission, a rapidly growing number of deaths and the lack of vaccine, countries all over the world introduced several restrictions, causing deceleration of the economy and limitations in nearly every aspect of life [14–16]. Problems with insufficient hospital beds for the patients, supply of ventilators and medicines, and even personal protective measures, such as protective gloves, masks or medical gowns became huge challenges for health care systems all over the world. Currently, the number of patients is growing quickly again [17]. The health care system has to guarantee safety and the possibility of treatment of patients in centres with all degrees of referentiality, including surgeries — both as a matter of urgency, e.g., as a result of injury or life-threatening conditions, and planned. Doctors, nurses, and the rest of the medical staff currently have to obey specific safety norms, also in the field of minimally invasive surgery [18–22].

During the pandemic, numerous new solutions have been introduced and some of the already existing ones have been improved to increase the comfort and safety, both of patients and healthcare professionals. In this context, international literature has been analysed to present new technological achievements, including medical robotics in procedure practice during the last months. The objective of the study is to indicate new scientific discoveries in the field of biomedical engineering and medical robotics, including Poland, keeping in mind specific circumstances — the time of a global pandemic of the coronavirus SARS-CoV2. An analysis of the problems resulting from the specificity of the operations which use medical robots in the context of the pathogen SARS-CoV2 has also been carried out.

During the process of the study, PubMed and Google Scholar databases were searched regarding the phrases: "medical robots", "robots", "covid-19" and corresponding Mesh Terms were used. More than 100 publications were selected, out of which 46 were chosen for the analysis. Due to the lack of numerous studies in the field of utilisation of the newest technologies during the last few months, media reports and producer's descriptions were also considered (15).

Dynamics of socio-economic changes during the pandemic

The announcement of the pandemic caused changes in every public sector. According to the forecast of the OECD (Organisation of Economic Co-operation and Development), the decline of Polish GDP can reach even 7.4% in 2020, in comparison with the previous year [23]. We are observing a complete reorganisation of the life of medical society. In Poland, the second semester of studies at medical universities was completed online; currently in an entirely online or hybrid form, and students of all fields of studies are using electronic solutions. In hospitals, volunteers were involved, who risked their lives completing the tasks given. During the period of the biggest escalation, scheduled admissions and procedures were suspended, and the surgeries were limited to the necessary minimum [20]. During the whole period of the duration of the pandemic in the territory of Poland, it is impossible to visit relatives in health care facilities.

A hospital stay can be an unpleasant and traumatic experience, both for parents and children, and the lack of possibility of meeting loved ones is an additional stress factor for the hospitalised and their families. The period of the pandemic is also dangerous, generating a huge psychological burden for the employees of the medical sector. Analysing an analogical situation — the Korean MERS epidemic from 2015, a prolonged normalisation period of ccf-gDNA and cc-mtDNA as indicators of psychophysical stress was observed in patients submitted to long-term isolation [24]. Since in times of the COVID-19 pandemic we are experiencing the biggest known isolation of individuals, similar results can be expected in the patients. Moreover, the experiences from massive infections with SARS and H1N1 show how big the psychological burden that the medical staff must deal with is. It is connected not only with an increased need for staff, causing the lengthening of working time of individual workers, constant changes of the safety protocol, but also with the fear of getting infected and infecting people who have contact with doctors, nurses, and the rest of medical staff. It is estimated that the probability of occurrence of PTSD among the members of the resuscitation team in a normative state is approx. 9.6%. The newest research shows an increase of this value during the COVID-19 pandemic up to over 10% [25].

In hospitals, the procedures introduced due to the possibility of infection with COVID-19 are obeyed with great diligence, nonetheless in many situations doctors, nurses and paramedics are at risk of a prolonged and repeated exposition to the infectious agent. It happens in Emergency Rooms and during each intervention of ambulance service.

Proposed new preventive measures against infections in times of COVID-19

In April 2020 dr Marcin Kaczor, an anaesthesiologist from the Medical University of Warsaw, presented his invention — the barrier tent, whose aim is to limit the spreading of the aerosol exhaled by the patients. The concept, which is cheap, easy to implement, efficient and which can increase the safety of the staff, was widely commented on all over the world [26, 27]. The creation of similar inventions is observed worldwide. An example of this can be the solution proposed by the scientists from the National Cheng Kung University, where a construction made of PVC was successfully used to inhibit the propagation of COVID-19 [28]. Another analogical protective measure for the staff and hospital environment is the Corona Curtain, which closes the whole patient in an artificial space, reducing the number of isolated rooms needed in a hospital unit [29]. All the solutions mentioned above or newly created are based on easily accessible and relatively cheap materials. It is especially important considering the range of the COVID-19 pandemic and the fact that in situations when a patient has been diagnosed with highly contagious pathogens, a risk of a prolongated exposition to the aerosol increases the risk of infection of third parties (patients suspected of being infected are treated as having a positive result until the results are obtained). Situations that cause the biggest risk are, among others, intubation, extubation or connection to a ventilator. There are also some solutions being created to protect (cover) the surgical field, for example, the protection of the staff in case of a planned tracheostomy procedure [34].

Securing patients' respiratory function

In the context of ventilators, the shortage of which took place during the first wave of the pandemic, it is important to mention a device which was presented by the scientists of the Institute of Biocybernetics and Biomedical Engineering of the Polish Academy of Sciences — VENTIL. VENTIL is a device that facilitates independent ventilation of a patient's lungs. In the aspect of dynamic growth of the number of patients with a developed or developing respiratory failure, requiring respiratory support, with a limited supply of ventilators, the function of the device which enables independent ventilation of two patients connected to one ventilator is a great solution for this problem. The Polish Academy of Sciences in collaboration with the Łukasiewicz Research Network — the Institute of Medical Technology and Equipment started a process of implementation and production of VENTIL, to meet the constantly growing needs of intensive medical care [35, 36]. In August, the FDA approved a product of Airway Medix Biovo Technologies — Cuff Pressure Regulator (Cuffix) to be released on the American market [37]. Cuffix is characterised by the producers as an innovative device that facilitates an automatic optimization of the pressure in the cuff which keeps in place the endotracheal tube. In the context of the large occupancy of beds in the intensive care units, Cuffix increases the chance of improving the safety aspect of the intubated patients and the quality of ventilation. The producer informs also about the exclusion of tracheal injuries and a reduced number of cases of pneumonia in the patients and, what is important in times of pandemic — about relieving the staff working in the intensive care units regarding taking care of the patients and monitoring parameters [38, 39]. Distribution agreements for supplying Cuffix have been signed, among others, in Brazil and Australia. Another interesting solution is UCL Ventura CPAP Device, created in collaboration with an engineering team Mercedes AMG High-Performance Powertrains [40]. The basic premise of said device is increasing the availability of ventilators for patients in critical condition through providing patients who present moderate symptoms with the help of CPAP. For this purpose, the structure of Whisper Flow, created in 1992 and fully mechanical, was analysed. The scientists, taking advantage of the expiration of patent protection, carried out a process of reverse engineering, creating in a short time a whole production line, which allowed them to provide more than 100 health care units with the devices.

Medical robotics in times of the COVID-19 pandemic

Medical robotics, which is developing faster and faster all over the world, and whose advantages are noted both by professionals and patients, is getting more popular also in Poland. According to the report prepared by PMR and Upper Finance Group, approx. 900 procedures have been carried out using the DaVinci system. Already in the first quarter of 2020, before the announcement of the pandemic, a 51% increase in the number of procedures was observed, in comparison with an analogical period the previous year. The pandemic stopped a further increase of the number of the procedures, but even now the experts are predicting its dynamic growth [41]. Globally, only in 2019 approx. 485 000 procedures were carried out in the field of general surgery.

There are numerous advantages of using robots in everyday clinical practice. Among many positive aspects, one can distinguish a greater precision of movement, reduced invasiveness of the procedures and better ergonomics of work [42, 43]. In an especially difficult time in the field of epidemiology — the COVID-19 pandemic, it is a very important issue to reduce the risk of a potential intraoperative and postoperative infection. Reduced invasiveness, a small surgery field and a unique precision reducing the risk of iatrogenic injuries, help diminish the risk of infection. Minimally invasive surgery has also a positive influence on a quicker return to normal activity and, thus, accelerates the process of recovery and leaving hospital — a place theoretically the most exposed to the occurrence of pathogens, which is, at the same time, overcrowded and often blocked for new admissions. The usage of a robot also helps to reduce the number of staff in the operating theatre — consequently reducing the risk of infection in a group of employees. The following months are going to bring solutions that could help to increase the number of procedures using medical robots, provided that appropriate safety measures are created [44–49]. The future can offer possibilities of increasing the popularity of teleoperations, which will enable such an activity of the surgeon that the effect could be to perform procedures in consecutive operating theatres, while he or she is still in the same place. A constant development, not only of medicine and robotics but also of telecommunication and informatics, can bring amazing results in the future in the field of surgical procedures and patient care. During the last few months, numerous European and international societies have made recommendations that specifically concern dealing with patients suspected of or diagnosed with COVID-19.

Currently, it is impossible to say with certainty what the long-term consequences of the infection with coronavirus will be in the people who recovered or in the people who did not experience the typical symptoms and in case of whom no treatment was implemented. COVID-19 currently is causing a so-called second wave of infections all over the world and the scientists, despite the intense work on the vaccine and treatment strategies, have not created obligatory populational solutions. Currently, the only approved medicine for the patients who require hospital treatment for COVID-19 is remdesivir. The FDA approved the medicine based on randomised research [50]. According to international research papers, it is possible to be infected with the coronavirus SARS-CoV2 more than once and an article published by the scientists from King's College London reports that the number of antibodies after the infection and having reached the peak decreases, and the rate of the decrease and the initial number itself depend on the severity of the disease. The authors of the study suggest that because of the results obtained, booster doses of a future vaccine may be needed [51]. The governments are preparing themselves to organize field hospitals — now, there is one open in the National Stadium in Warsaw and there are more being planned. The most serious problem is, however, the lack of staff, whose number is also reduced because of physicians getting ill. In the context of insufficient backup staff, the need for the development of medical robotics and artificial intelligence should also be considered — robots that could work at patients' beds, disinfecting and cleaning, as well as systems analysing laboratory results and imaging tests of the patients. It is also possible to implement remote ultrasound scans, using mobile 5G technology, which was planned and carried out by Ruizhong Ye with the team [52]. Another research carried out by the scientists from China, to detect potential heart damage during COVID-19, concerns the evaluation of left ventricular ejection fraction, the activity of the right ventricle and overall heart activity. In a tele-echocardiography test using a robot, J. Wang with the team showed that a diagnostic procedure is possible and brings a satisfactory result, and is, moreover, safe for the doctors, reducing the risk of infection with the virus and facilitates monitoring the dynamics of the progression of the illness [53]. The patients who, during hospitalisation or quarantine resulting from the infection with COVID-19, require interventional treatment, should also be considered. Robotically supported coronary interventions — also remote — in addition to precise and accurate performance, would possibilitate epidemic protection of doctors and support staff during the procedure. Oncological patients often also require surgical intervention. About the advantages, which have already been mentioned, informs also Felsenreich D.M. and co-workers [54]. During the pandemic, health care centres where robotic surgeries were performed maintained a high standard of treatment, carrying out procedures according to plans. It is obvious that the number was lower than the year before, but from mid-year, an upward trend can be noticed. In Poland, it still lacks solutions that could influence the development of medical robotics and its widespread adaptation in the health care sector.

However, the dangers resulting from the use of minimally invasive surgery, including robotic surgery, should also be pointed out. As a potential problem, SAGES (Society of American Gastrointestinal and Endoscopic Surgeons) and The Royal College of Surgeons indicate the moment of insufflation during the procedure. Theoretically, it is possible for CO2, which is used for this purpose, to be a transmitter for COVID-19, putting the staff at risk of exposition [55]. It should be emphasized, however, that the procedures of open surgery are not free from the risk of the creation of an aerosol containing infectious material.

Initiatives were created to implement new solutions in the field of AI and medical robotics, which could support the fight with the crisis related to the COVID-19 pandemic. The European Commission created a project called AI-ROBOTICS vs COVID-19; another program is Digital Innovation Hubs in Healthcare Robotics. In Poland, additional funding has been allocated to carry out clinical research within the Medical Research Agency and the National Centre for Research and Development.

Very little research shows the number of positive aspects connected with the use of robots in surgical procedures in times of the COVID-19 pandemic. Their use in imaging tests, which constitute a very important element in the diagnosis of SARS-CoV2 and potential complications after the infection, should also be noted. The development of robotics in the context of remote decontamination of the rooms where the patients infected with the infectious agent have been staying is also worth mentioning. An example can be here i-Robot UVC, which successfully disinfects the areas of treatment of COVID-19 positive patients [56]. Another interesting solution centred on the preservation of elderly patient's psychological well-being during times of pandemic is the concept of social robot suggested by Nancy S. Jecker [57]. It is an alternative for solutions in the form of classical video calls. Attempts of adapting already existing solutions from the field of assisting robots, aimed at creating tools to improve elderly patient's psychological well-being during times of pandemic, are also being suggested [58]. According to media reports, robots are also used to support nursing staff and for patient observation. An example is Tommy robots used in Italy [59].

Keeping in mind patients' and staff's well-being, especially in the aspect of exposition to the pathogen, the number of procedures using robots should increase dynamically. The development of medical robotics in times of pandemic, as well as after its end, should be a priority both for the medical community and for the people responsible for taking decisions related to education, research integration and business, as well as for people who plan benefit budgets. An example can be the Military Medical Institute in Warsaw, which in July 2020 signed a contract about buying another surgical Da Vinci robot, or the first NAVIO in Poland, which also appeared in Ostrów Mazowiecka during the global pandemic [60, 61].

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