New Tasks for Medical Robotics in Rehabilitation and Hospital Services in a Pandemic Time – New Solutions: a Concept Model of an Autonomous Multifunctional Robot «Helper»

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Abstract

The article is devoted to an overview of modern medical robots used in everyday rehabilitation practice and hospital services. At the same time, the emerging problems and new challenges associated with the COVID-19 pandemic are analyzed. Logically structured medical and technical solutions using innovative robotics are proposed. The concept model of the multifunctional autonomous robot "Helper" which is presented in the article has 7 functions that are critical in the face of a pandemic: movement along the specified routes; disinfection of premises and robot self disinfection; biometric identification; delivery of medicines; interpersonally communication; possibilities of telepresence and telemedicine; interactive musical-acoustic and virtual psychotherapy. It is an attempt to find effective practical response to the most serious challenges of our time associated with the pandemic aimed at reducing the risks of nosocomial spread of infection, unloading medical staff, providing psychological and service assistance to patients with COVID-19 who are undergoing rehabilitation treatment. The conclusive idea of the article is that medical robotics plays an increasingly significant role in the process of modern rehabilitation treatment and hospital services, which become especially important during a pandemic control and liquidation of its consequences. The relevant robotization of Healthcare Service has strategic importance with high medical, social and economic potential.

Keywords: medical robotics, rehabilitation, pandemic COVID-19, disinfection, drugs delivery, musical psychotherapy, telemedicine

Introduction

In the 21st century, robotics has entered almost all spheres of activity of our civilization. Medical robotics has made particularly rapid leap over the past two decades which has a wide range of varieties.

For instance, surgical robots which are remotely controlled help doctors to perform highly accurate and minimally invasive operations. There are also robotic assistants which deliver drugs and food to patients and staff; rehabilitation robots; robots-disinfectors; robot-companion or empathic robots which assist in the elderly care or patients with physical/mental disabilities; robots for psychotherapy. Finally, nanorobots which are equal to molecules are designed to carry out the certain programs inside their bodies and they are able to move, to take, to analyze and transmit different information. Medical robotics is now used in almost all areas of healthcare in developed countries. According to the conviction of experts from the United States of America, the use of robotics in health care can provide with high-intensity therapy [1]. Under the auspice of the EU-funded COST program, the European Robotics Network for Neurorehabilitation was established. More than 100 researchers, clinicians and engineers from 23 European countries took part in the project to:

– coordinate, optimize interdisciplinary research for a better understanding of robotic rehabilitation;
– promote evidence-based research in robotic rehabilitation;
– develop clear evidence-based indications for robotic therapy and patient selection guidelines;
– to define the necessary functions for new and effective treatments using robots [2].

The development of new technologies for neurorehabilitation by robotic devices is one of the important directions in the search for innovative recovery strategies [3].

Main types of rehabilitation robotics

1. Rehabilitation robots which are divided into assistants and therapeutic robotic systems play an important role in restoring physical activity and improving the quality of handicapped people life;
2. Assistant robots are meant to help people with reduced capabilities in solving urgent everyday tasks, who cannot do their job due to their health condition, for example, some social and domestic actions. Robots can bring some food to the mouth of a disabled person or turn over pages in a book. In this case stationary robots are fixed in a certain po-

sition on workstations and are controlled by typed commands through various devices. Mobile robots on the other hand typically consist of a movable arm fixed either on a mobile platform or on the lateral side of a motorized wheelchair [4];

3. Rehabilitation robotics for therapeutic purposes includes various types of programmable stationary or portable electromechanical devices and fitness equipment, the main purpose of which is to recover disordered function of organism in the first instance motor inducted by neurological disorders or trauma [2];

4. The motor function recovery in among patients with cerebral spinal injury, despite the development of modern medicine, remains a serious problem. Recovery level after spinal cord trauma is often small and many patients stay wheelchair-bound. As a result of low physical activity, secondary affection gradually develops among victims (osteoporosis, obesity, cardiovascular, respiratory, genitourinary, trophic and other disorders), the confounding flowing of the basic disease and the complicating the process of medical rehabilitation [5];

5. Improvement of functional mobility and general health condition can be achieved with the use of robotic devices [6]. It is expected the growth of robotic devices focused on specific rehabilitation therapy for a patient at home [7]. Reasonable hopes tied to the use of exoskeletons and computer-aided systems of movement;

6. Exoskeletons are wireframe devices which are fixed outside of the human body and are meant for improvement of lost/reduced motor functions, the increasing muscle strength and range of movement;

7. There are active models of exoskeletons which use external devices as a source of energy and are used in rehabilitation, whereas the passive exoskeletons which have mainly military use are based on the use of kinetic energy and human strength. Besides, there are also exoskeletons of the upper/lower limbs and exoskeletons suits [8];

8. The Matsushita Company has developed a robotic exoskeleton suit for the rehabilitation of patients with paresis (fig. 1). The special compressors activated on the opposite side when person uses the healthy arm in exoskeleton suit. They play the role of muscles, and the weakened arm repeats the movement. Thanks to this training paretic limbs can be recovered to a normal state of motor activity [9].

An equal important task for the rehabilitation of patients with spinal problems is to recover walk ability. It was revealed that the training program in the «ExoAtlet» exoskeleton normalizes the muscle tone of the lower extremities and improves the psycho-emotional background in the examined patients [10].

It was found that the inclusion of the «ExoAtlet» exoskeleton in the neurorehabilitation complex gave an advantage in the progress of neurological status in patients with cerebral spinal injury compared with traditional gait restoration technologies [11].

Positive results of the rehabilitation of patients with the consequences of spinal cord injury were got through a mix of the exoskeleton using with the functional electrical stimulation of the lower limbs. When compared with the control group that received the traditional rehabilitation complex, the electromyography parameters of the back muscles and

Fig. 1. *Exoskeleton suit*

hip joint extensors, the biomechanical parameters of walking and the psychological status scale in the main group looked more preferable. At the same time, the walking of the patients of the main group became more stable and less energy-consuming. Trainings with the use of an exoskeleton ameliorated to a significant improvement in the psychological status, and in general, expanded the functions of self-care and mobility among patients of the main group [12].

Robotic systems for movement are designed to optimize the repetitive training required for improving motor function among patients with disorders tied to neurological diseases [9].

The loss of motor function is a hallmark of neurological diseases such as infantile cerebral palsy, sclerosis, Parkinsonism, stroke, amyotrophic lateral sclerosis, traumatic lesions of the spinal cord and brain. Neurological rehabilitation is oriented to retrain motor skills. Although the necessity for rehabilitation is evident for the recovery of post-stroke patients, as well as for patients with previous spinal cord and traumatic brain injuries, many of these patients cannot participate in conventional rehabilitation programs because of existing movement disorders, for example, hemi paresis, balance disorders, which critically restrict patients in movement and pose the risk of repeated injuries [13].

Under the circumstances, early intensive and long-term rehabilitation of advanced robotic devices are critical factors for achieving good results [14]. The intensity of rehabilitation leads to staff costs increasing and the time limitation for hospital staying is a restriction. In this scenario robotics can make possible to increase the effectiveness of the physical activity rehabilitation [15]. A number of randomized controlled studies presented that rehabilitation robotics is able to effectively restore the functions of both the upper and lower limbs in among post-stroke patients [16]. A meta-analysis has shown that arm training with robotics improves

Fig. 2. *The «Lokomat Pro» technological complex*

the quality of daily life and also the motor activity of the upper limbs [17]. Rehabilitation-oriented repetitive movement exercises, balance training, and the using of a robotic running track can improve muscle strength and motor coordination in among neurological patients with movement disorders [18, 19].

The example of such a robotic device is the «Lokomat Pro» technological complex (fig. 2), which consists of four actuators for movements controlling, a patient's lose weight system and a running track, which makes possible to conduct movement therapy with closed-loop.

It was shown that the using of robotic therapy with the «Lokomat Pro» complex among patients with post stroke hemi paresis has an evident reconstructive effect than among patients who undergo rehabilitation using the same scheme but without robotic therapy. At the same time, it was found that the patients over 65 years old had the results of trainings using the «Lokomat Pro» complex lower and in some cases there is a complete lack of dynamics or even a negative result [20].

The modern world almost wholly depends on advanced technology, therefore elaboration of robotics, software, computer control systems, including a Brain-Computer Interface which provides a communication path between the human brain and the computer system for Physically Handicapped People is prospective direction of development [21–24].

New tasks of rehabilitation robots in a pandemic time

The COVID-19 pandemic has had a huge impact on all spheres of modern life of the world's population and has identified new challenges facing the global health system, including medical service and rehabilitation.

An increasing flow of patients with respiratory, psychosomatic and stress-related disorders after the corona virus infection has joined the usual contingent of rehabilitation centers. Treatment-and-prophylactic institutions work with great overload, there is not enough medical staff.

At the same time, the risk of repeated outbreaks of corona virus and the other types of dangerous infections remains. According to recent events, repeated outbreaks of COVID-19 in Germany and China, confirm these concerns. Among the identified foci of reinfection medical and social institutions are in the first positions.

In order to enhance the effectiveness of remediation of a pandemic in a rehabilitation centers and in hospitals, it is necessary to define the main challenges for time-critical issue.

These challenges include:
– Lack of specific anti-corona virus drugs and vaccines with proven efficiency, in the course of high contagiousness of the virus;
– The risk of the spread of corona virus and the other types of infection in health care facilities;
– Psychophysical overload of the medical staff and lack of personnel;
– An increasing number of patients with stressful and psychosomatic disorders;
– An increasing number of patients with adverse respiratory effects after suffered from corona virus pneumonia.

The institutes of different countries are engaged in the search for antiviral drugs and vaccines, and there is no doubt that these tasks will be solved in the near future. However, challenges 2–5 will remain relevant for a long time.

It should be understood that for many disabled patients who undergoing rehabilitation treatment in rehabilitation centers, for example, with movement disorders after strokes or traumatic brain injuries, a corona virus infection or another type of infection can be fatal.

Besides, the epidemiological, pharmaceutical and biotechnological efforts undertaken by the health care system as a whole, a number of complex measures are needed in medical institutions of a rehabilitation profile to maximize the effective response to the challenges in a pandemic.

1. Regular disinfection of all rooms and public places;
2. Minimizing contact of medical staff with quarantined persons;
3. Introduction of programs for early rehabilitation of respiratory disorders after suffered from corona virus pneumonia;
4. Widespread use of psychotherapy and psycho correction methods in rehabilitation programs for patients of any profile, including patients with stressful and psychosomatic disorders after COVID-19.

It is obvious that the implementation of these tasks is a huge additional burden both for the budget of medical institutions and for the staff, the shortage of which has recently been very noticeable.
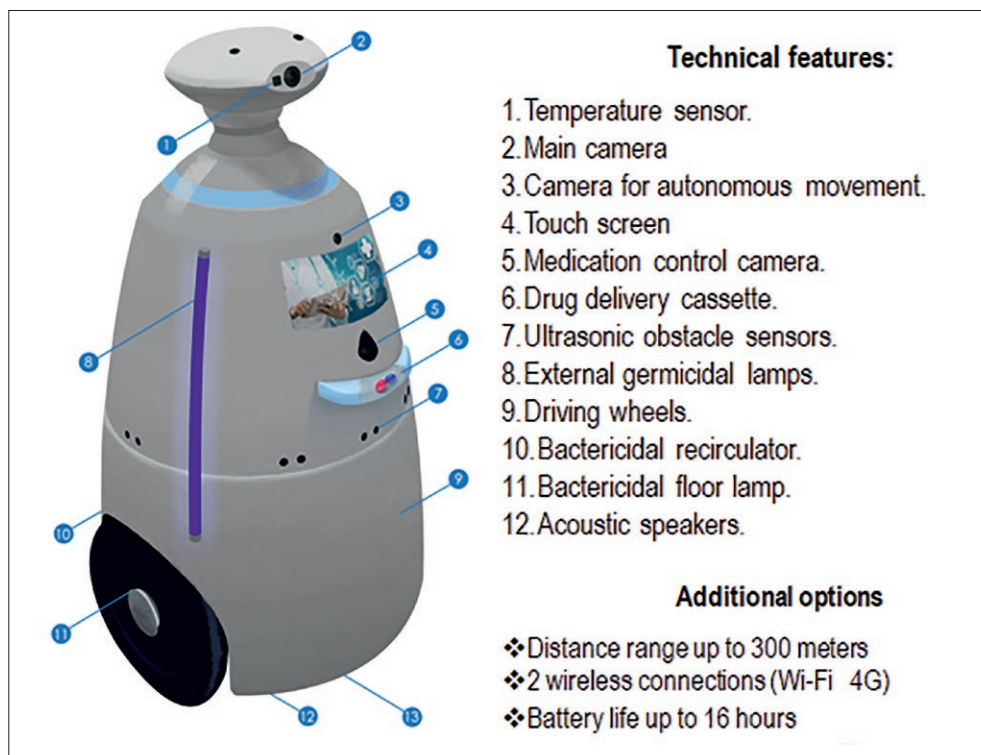
In a pandemic, the intensive connection of robotics and IT-technologies is critically necessary to the work of rehabilitation centers and the other medical institutions. In this case it is needed new generation robotics, with a set of functions capable to solve holistically the most pressing challenge.

The autonomous multifunctional medical robot «Helper» and its capabilities

In 2019 we created an autonomous medical robot based on the R. Bot 100 Plus platform, known for its large work resource and high reliability. A pilot sample could move along the specified routes, communicate, carry out biometric identification and select health-improving music tracks [25].

Currently, to the basic capabilities of the robot, called «Helper» we have added 4 functions that are critical in the face of a pandemic:

1. Disinfection of premises and robot self disinfection;
2. Delivery of medicines;
3. Musical-acoustic and virtual psychotherapy;
4. Possibilities of telepresence and telemedicine.

Technical features:

1. Temperature sensor.
2. Main camera
3. Camera for autonomous movement.
4. Touch screen
5. Medication control camera.
6. Drug delivery cassette.
7. Ultrasonic obstacle sensors.
8. External germicidal lamps.
9. Driving wheels.
10. Bactericidal recirculator.
11. Bactericidal floor lamp.
12. Acoustic speakers.

Additional options

❖ Distance range up to 300 meters
❖ 2 wireless connections (Wi-Fi 4G)
❖ Battery life up to 16 hours

Fig. 3. *Technical features of the multifunctional autonomous robot «Helper»*

The Helper robot has a male and female speech synthesizer, the ability to connect to interactive services, and is able to work both autonomously and under the control of a remote user/operator.

With a height of 105 cm robot has a weight of 45 kg, is capable of operating from a rechargeable battery up to 12 hours, self-charging up to 5 hours. The technical features are shown in figure 3.

1. Disinfection of premises and self-disinfection. The «Helper» robot is capable of automatically performing complex disinfection of premises up to 150 sq. m., medical offices, wards, halls and corridors, public places. This gadget is capable of identifying person and also switching over to safe for people mode of disinfection.

External germicidal or UV lamps (8) are used as equipment for disinfection of empty rooms and a built-in air recirculator with filtration and radiation disinfection (10), a bactericidal lamp for the floor are used as equipment for disinfection of rooms with human presence (11).

2. Personalized medicines delivery. Under the conditions of increased epidemiological danger, medicine delivery and medical consumables (if necessary) give the possibility to prevent infection of medical staff and patients. The technical support is carried out by using a multi-section self-retractable cassette (6), which is pre-filled with medicine by medical prescription. The self-disinfection option excludes the possibility of contact infection of transported medicines, and the biometric identification function of people allows to control medicine delivery.

3. Musical-acoustic and virtual psychotherapy. The corona virus pandemic has found out a serious problem such as various stress disorders and panic attacks, which became widespread among patients and the population of the planet.

Based on the advanced achievements of scientific music therapy, bioacoustics and psychology, innovative programs for psycho diagnostics and music-acoustic psychotherapy in digital format have been developed, which are included in the robot's functionality. It has been found that their use is an effective way to relieve stress and various psychosomatic disorders [25, 26]. Two loudspeakers (или acoustic speakers), 20W each (12), transmit high-quality sound.

A 7-inch touch screen existence (4) allows to carry out the robot another innovative method such as virtual music-art therapy where the world masterpieces of musical art and painting are the digitized programs.

At the same time, these methods of psychological relief can be used both in working with patients and with medical staff.

Telepresence and telemedicine

With the help of the main telepresence camera (2) and the robot it is possible to conduct various remote trainings and rehabilitation programs. So, for example, for the correction of respiratory disorders among patients after corona virus pneumonia, the use of vocal therapy is needed as an effective method of rehabilitation treatment through singing. Also the patients who are quarantined can use early intensive rehabilitation participating in online trainings such as breathing exercises, physiotherapy complexes and etc.

At the same time, two-way remote communication eliminates the risk of mutual infection of patients and medical staff.

Conclusion

Medical robotics plays an increasingly important role in the process of modern rehabilitation treatment and hospital services, which become especially important during a pandemic control and liquidation of its consequences.

What can be expected at the present time in case of systematic implementation of the autonomous multifunctional «Helper» robot into medical and rehabilitation practice?

– Significant decrease of intrahospital infection due to robotic disinfection and telemedicine;
– Improvement of the epidemiological situation;
– Expanding the range of provided services of medical rehabilitation and also using the telepresence function;
– Psychological and industrial unloading of the medical staff;
– Improving the intensification and working efficiency of the medical institution.

Thanks to the combination of several intercomplementary functions, the «Helper» robot will also be extremely useful for medical institutions of any profile, not only in extreme situations, but also in everyday practice.

The relevant robotization of Healthcare Service has strategic importance with high medical, social and economic potential.

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