

Healthcare Workers' Point of View on Medical Robotics During COVID-19 Pandemic – A Scoping Review

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Abstract: COVID-19 affected how healthcare workers interact with patients. Medical technology and robotics are developed in hospital settings to limit human contact. The aim of this review is to elucidate what kind of medical robotics is required for healthcare workers during COVID-19 pandemic. This review was obtained from electronic databases such as Google Scholar, PubMed, EBSCO, and Cochrane reviews were searched for articles using keywords such as “healthcare professional” OR “health worker” AND “COVID-19” AND “robot application” OR “robotics” OR “health technology” AND “needs assessment” OR “expectation” OR “perception” published during 2020 to 2021. Inclusion criteria were full-text articles related to assessment of healthcare workers’ need for medical robotics during COVID-19 pandemics. Exclusion criteria included abstracts, duplicate articles, blogs, news articles, promotional brochures, and conference proceedings. A total of 13,692 articles were identified through the search engines (PubMed 179, Cochrane Library 1300, EBSCO 13, Google Scholar 12,200). Five full-text articles fulfilled the inclusion criteria. Determining robotic functions is important to healthcare workers who will be user of such medical technology. This review divided robotic functions into medical, operational, movement, and social functions. Healthcare workers’ demands for robotics were also influenced by the types of robots, such as examination robots, robot-based sample test and medicine production, surgery and rehabilitation robots, disinfection and cleaning robots, delivery and logistic robot, telemedicine, and telepresence robots. Medical robotics is required for healthcare workers during the COVID-19 pandemic. The highest demands for medical robotics functions include cardiac measurements and oxygen saturation monitoring (medical functions); examination record delivery, video and image play, and medical information delivery (operational functions); and the ability to recognize and avoid obstacles (movement functions). Disinfection and cleaning robots were the type of robots with the highest demand among healthcare workers.

Keywords: COVID-19, health worker, medical technology, need assessment, robotic

Introduction

In recent decades, there has been considerable advancement in technologies, computer science, machine, and robots.¹ This advancement has resulted in the introduction of various types of robots into the great majority of businesses, including industry, military, medical and healthcare, entertainment, and domestic.¹ Requirement of robotics in healthcare is increasing day by day. Robots applications in healthcare including receptionist, nurse, ambulance, telemedicine, hospital serving, cleaning, spraying/disinfestation, surgical, radiologist, rehabilitation, food, and outdoor delivery robot.²

The COVID-19 pandemic posed a considerable number of challenges, including a lack of healthcare centres, specialists, and services, as well as significant financial burdens related to healthcare costs.^{3,4} The pandemic has altered how clinicians interact with patients. To safeguard healthcare workers and prevent the spread of severe acute respiratory

syndrome, protocols for the use of personal protective equipment, social distancing, as well as triage facilities for screening symptomatic patients have been developed.^{5–10}

While the research for COVID-19 pharmacotherapies and vaccinations continues, numerous healthcare systems have enhanced their medical technology and robotic capabilities to restrict human contact while allowing triage of patients who may have COVID-19.^{7,11} The utilization of mobile robotic devices operated by physicians can promote a dynamic evaluation procedure in the hospital context.¹²

Before using robotic systems extensively to offer patient care during COVID-19 pandemic, it is necessary to assess the acceptance and need for this technology among healthcare workers. This scoping review aimed to elucidate what kind of medical robotics is required for healthcare workers during the COVID-19 pandemic in order to improve health services to our patients.

Materials and Methods

Our review was based on articles published from 2020 to 2021 obtained from PubMed, Google Scholar, EBSCO, and the Cochrane Library databases, using the following keywords: “healthcare professional” OR “health worker” AND “COVID-19” AND “robot application” OR “robotics” OR “health technology” AND “needs assessment” OR “expectation” OR “perception”. The search was performed from August to September 2021.

Inclusion criteria were full-text articles related to the assessment of health professionals’ need for robotics in healthcare during the COVID-19 pandemic. Only the first 100 Google Scholar searches were considered for eligibility, as searches beyond 100 articles were repetitive and unrelated to robotics in healthcare. Only English-language articles were included. Exclusion criteria were abstracts, duplicate articles, blogs, news articles, promotional brochures, conference proceedings, articles not related to robotics in healthcare, articles not mentioning COVID-19, and articles not related to the assessment of health professionals’ need for robotics (Figure 1).

Articles retrieved from the literature search were screened at the title level by the first author. Four reviewers (SC, SI, AT, DN) independently verified the accuracy and eligibility of the full-text articles. A consensus and consultation with a fifth reviewer (AQ) resolved any disagreement in the selection process.

Results

A total of 13,692 articles were identified through the search engines (PubMed (n=179), Cochrane Library (n=1300), EBSCO (n=13), Google Scholar (n=12,200)) (Figure 1). Searches from the Cochrane Library found no systematic reviews on the assessment of medical robotics need during COVID-19 pandemic. Five full-text articles fulfilled the inclusion criteria and were published from 2020 to 2021 on the assessment of medical robotics need for healthcare workers during COVID-19 pandemic (Table 1).

Understanding end-user demands is a critical first step in developing an acceptable medical robotic system.^{13,14} It is crucial to determine which functions are required and which elements are important to the healthcare workers who will become the user medical robotics technology. This review divided robotic functions into medical, operational, movement, and social functions.¹⁵ Medical functions are robot capabilities in medical needs, such as cardiovascular monitoring, temperature measurement, and stress evaluation. Operational functions are robot capabilities in system operations, including delivery function, video and image play, voice recognition, and laser point. Movement functions are robot capabilities in obstacle avoidance, wireless system, automatic navigation, docking station, automatic camera movement, robotic arms and legs movement, turnover, and height adjustment. Social functions are robot capabilities in social interactions.¹⁵

Healthcare workers’ demands in robots were also influenced by the type of robot, such as examination robot, robot-based sample test and medicine production, surgery and rehabilitation robots, disinfection and cleaning robots, delivery and logistic robot, as well as telemedicine and telepresence robots.^{16–19} The required function and type of medical robotics is different between doctors and nurses (Table 2).

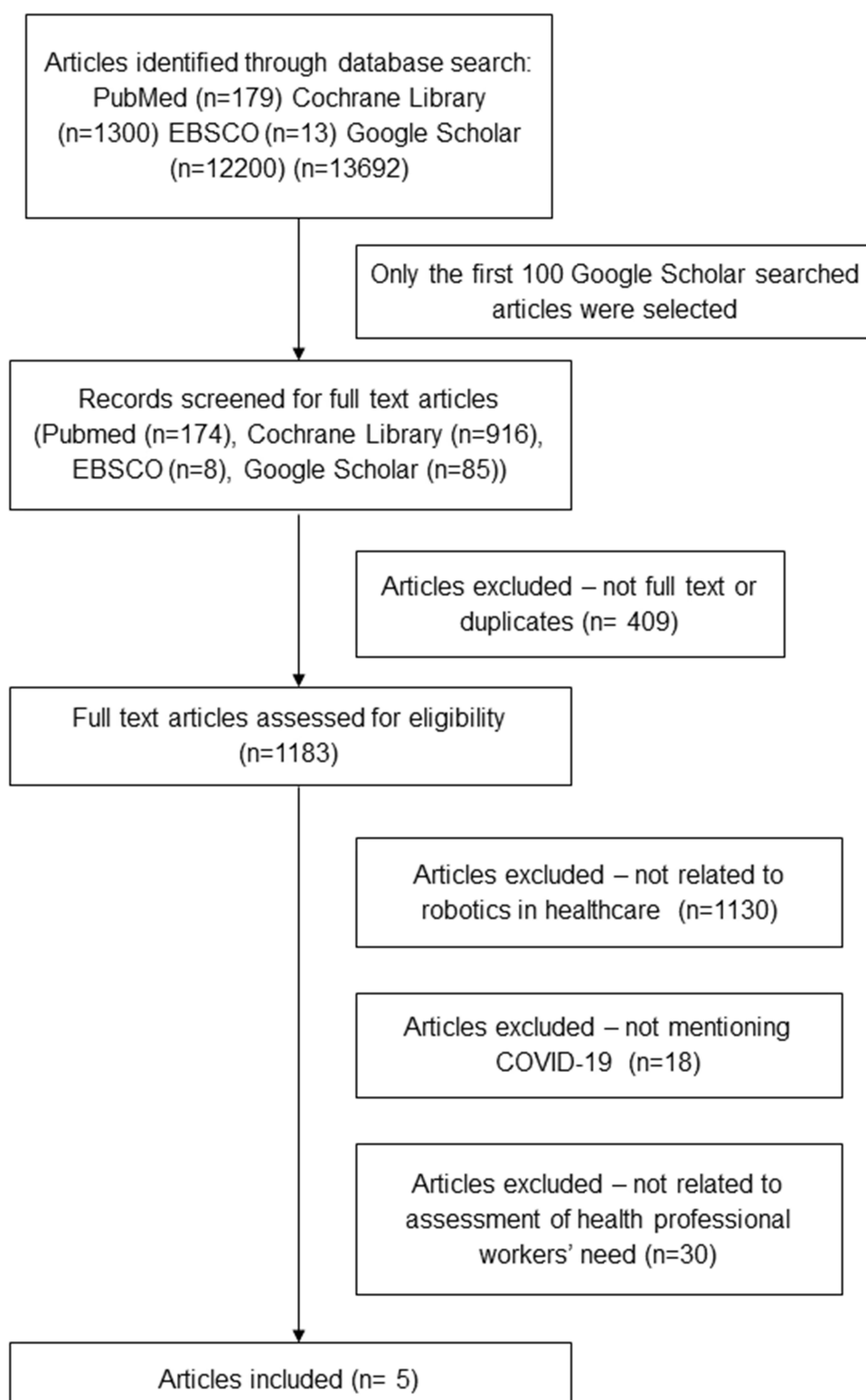


Figure 1 Flowchart of article selection.

Table I Summary of Assessment of Medical Robotics Requires Among Healthcare Workers During COVID-19 Pandemic

No.	Reference	Country	Participants	Scope/ Domain/ Elements	Type of Article	Main Findings
1.	Jang et al, 2020 ¹⁵	Vietnam	Doctors and nurses	Medical function, operational function, movement function	Original article	<ul style="list-style-type: none"> Medical functions: Heart rate monitoring, Oximeter, Blood pressure measurement, Blood glucometer, Recognition of nonverbal signals, Temperature measurement, Electronic stethoscope, Penlight, Stress evaluation, Ruler Operational functions: Examination record delivery, Medical information delivery, Video and image play, Voice recognition with contextual perception, Touchscreen, Videotaping or sound recording, Voice command, Bidirectional videoconferencing system, Video screen capture, Image file sharing, Statistical value display, Screen sharing, Onscreen messages to notify users of significant conditions, Laser pointer (for indicating), Messaging, Video transmission and reception of simultaneous confirmation Movement functions: Obstacle avoidance, Wireless system, Automatic navigation, Docking station, Automatic camera movement, Robotic arms and legs movement, Turnover, Height adjustment
2.	Wang et al, 2021 ¹⁶	All countries	Healthcare Professional	Examination robot; Robot-based sample test and medicine production; Healthcare, telepresence and monitoring robot; Surgery and rehabilitation robots; Disinfection and cleaning robots; Delivery and logistics robot	Literature survey	Swapping robot, Ultrasound and examination robot, Remote examination robot, Testing device, Preparation device, Automated medicine production, Servicing robot, Telepresence robot, Surveillance robot, Monitoring robot, Surgical robot, Remote rehabilitation robot, Disinfection robot, Cleaning robot, Delivery robot, Goods preparing robot
3.	Sierra et al, 2021 ¹⁷	Colombia	Healthcare Professional	Disinfection and cleaning robots; Assistance, service, and logistic robots; Telemedicine and telepresence robots	Original article	<ul style="list-style-type: none"> Disinfection and cleaning robots: noiseless, user friendly, safe, accurate, autonomous, provide cleaning; Assistance, service, and logistic robots: accurate, provide interaction, distribution of medicines, monitoring, mitigation, safe, provide alerts, provide support; Telemedicine and telepresence robots: safe, trusted, accurate, provide alerts, provide support, communication, provide interaction

4.	Atashzar et al, 2021 ¹⁸	All countries	Healthcare professional, patients with neuro-musculoskeletal conditions	Teleoperated robots, Autonomous collaborative robots, Exoskeleton robots, Smart wearable mechatronic systems, Hand-held robots, Social robots	Literature review	Teleoperated robots, Autonomous collaborative robots, Exoskeleton robots, Smart wearable mechatronic systems, Hand-held robots, Social robots
5.	Feroz et al, 2021 ¹⁹	Low-and-middle-income countries	Community Healthcare Workers (CHWs)	Digital tools for prevention, detection, management of COVID-19	Literature review	Digital tools for prevention, detection, management of COVID-19

Table 2 Summary of Healthcare Workers' (Doctors and Nurses) Required for Robotic Functions

No.	Domain	Doctors	Nurses
1	Medical function	Yes	Yes, higher preference ¹⁵
2	Operational function	Yes	Yes, higher preference ¹⁵
3	Movement Function	Yes	Yes, higher preference ¹⁵
4.	Social function	Yes	Yes, higher preference ¹⁵
5.	Examination robot	Yes, higher preference ²³	Yes
6.	Robot-based sample test and medicine production	Yes ²⁷	Yes ²⁷
7.	Surgery and rehabilitation robots	Yes ¹⁸	Yes
8.	Disinfection and cleaning robots	Yes ¹⁵	Yes ¹⁵
9.	Delivery and logistics robot	Yes ¹⁷	Yes ¹⁷
10.	Telemedicine and telepresence robots	Yes ¹⁷	Yes ¹⁷

Discussion

Robots' Requirements Analysis

Medical Robots' Requirements Analysis

Robotic medical function included heart rate monitoring, oximeter, blood pressure measurement, blood glucometer, temperature measurement, electronic stethoscope, penlight, stress evaluation, and ruler (length measurement) functions.¹⁵ According to studies by Jang et al, the three highest rankings of robotic functions required by healthcare workers are heart rate monitoring, oximetry, and blood pressure functions. Heart rate monitoring function was the most critical patient observation equipment to add to the medical robot.¹⁵ The required functions of medical robots differed were significantly between doctors and nurses. Nurses expressed an increased demand for stress evaluation compared to doctors ($p = 0.004$).¹⁵ Most nurses preferred heart rate monitoring, blood pressure, and oximetry functions for medical robots. Furthermore, most doctors also preferred heart rate monitoring and blood pressure measurement functions for medical robots but this was not statistically significant.¹⁵

Operational Robots' Requirements Analysis

Medical robotics operational functions included examination record delivery, medical information delivery, video and image play, voice recognition with contextual perception, touch screen, videotaping or sound recording, voice command, bidirectional videoconferencing system, video screen capture, image file sharing, statistical value display, screen-sharing, onscreen messages to notify users of significant conditions, laser pointer (for indicating), messaging, as well as video transmission and reception of simultaneous confirmation.¹⁵

Healthcare workers' three highest demands for operational functions included examination record delivery, video and image play, and medical information delivery.¹⁵ For nurses, voice command, voice recognition with contextual perception, zoom in/out, and onscreen messages to notify the users of operational functions were more required compared to doctors.¹⁵

Movement Robots' Requirements Analysis

Medical robotics movement functions included obstacle avoidance, wireless system, automatic navigation, docking station, automatic camera movement, robotic arms and legs movement, turnover, and height adjustment.

According to a study by Jang et al, the ability to recognize and avoid obstacles was in high demand among healthcare workers. Some medical robots have self-driving or follow-up capabilities.^{20,21} However, before this feature may be used in medical settings, safety must be maintained, possibly by integrating devices to recognize and avoid nearby obstacles or deceleration to avoid crushing into patients.¹⁵ Obstacle avoidance is an essential function in a medical setting to ensure

the safety of both patients and providers. Obstacle avoidance was in higher demand among doctors compared to nurses.¹⁵ The second highest demand from healthcare workers was for wireless system, which may boost the mobility of medical robots. A wireless robotic system was designed to address scenarios where the patient could not move. Jang et al's study demonstrated that medical robotics could quickly react to an accident or emergency involving the target person via a wireless system.¹⁵ The demanded movement functions of medical robots were differed significantly between doctors and nurses. Turnover, robotic arms and legs movement, and docking station functions were more required for nurses than doctors because these functions can assist the nurse's task in direct patient care and maintaining medical devices.^{15,22}

Social Robots' Requirements Analysis

Medical robotics social functions included recognition of nonverbal signals (eg, users' facial expressions) and voice interaction (context-aware speech recognition). Nurses generally scored these items higher than doctors.¹⁵

Types of Medical Robotics

Examination Robot

The application of robots begins with patient testing, where the robot can screen for COVID-19 cases.¹⁶ To collect swabs from patients, an oropharyngeal swab robot was created. Oropharyngeal swab robot could prevent cross-infection between health worker and patient. Li et al showed that oropharyngeal swab robots had a similar rate of detected pathogen compared a manual swab. The oropharyngeal swab robot has a high demand in clinical practice during COVID-19 pandemic.²³ Another examination robot is robotic ultrasound. To limit exposure to the disease, the sonographer and the patient were isolated using remote robotic ultrasound instruments. Network robotic ultrasound is needed in rural or low-volume centers because patients can receive ultrasound services faster without being transferred to distant imaging centers.^{16,24} Furthermore, radiologist robots have special demand due to high levels of radiation and safety concerns for human operators.²⁵

Robot-Based Sample Test and Medicine Production

After collecting samples, the next step is to test them quickly and obtain the results. A robotic approach for high-throughput screens was presented to find decisive therapeutic targets against the virus.²⁶ To detect the virus and related medication targets, it is usual to employ a robot and an automated platform.

After the virus is detected and the disease is confirmed, it is critical to manufacture medications and vaccinations as soon as possible. Medicines and vaccines are produced automatically using robots and automated machinery.¹⁶

Despite their great potential in SARS-CoV-2 settings so far, medical robotics in patient-facing scenarios remained limited. The primary concern is about the robot's high cost, limited patient-facing function, and possible harmful influence on the patient, medical staff, and their interactions. However, lab-based robot is projected to have excellent safety and sufficient gains in performing sample extraction and amplification.²⁷

Surgery and Rehabilitation Robots

In a difficult and minimally invasive operation, surgery robots are recommended. Surgery robots can reduce the length of patient care, enhancing other patients' availability and are becoming useful during the pandemic. The benefits of surgical robots, such as reduced contact and contamination, shorter duration of inpatient treatment, less blood loss, and smaller incisions promote surgical use, particularly in a pandemic.^{16,28,29} According to Sparwasser et al, surgical robots could be adopted safely for patients and healthcare workers. There was no COVID-19 transmission among 60 healthcare workers who had direct contact with patients during robotic surgery.²⁸ This is similar to Zemmar et al's study that showed surgery robots could reduce contamination before, during, and after the operation.²⁹

In addition to surgery robots, rehabilitation robots are also needed to reduce infection transmission during the pandemic. Rehabilitation robots can minimize patient-therapist contact, reduce infectious disease transmission through home rehabilitation devices, and assist patients with disabilities.^{16,30,31} Furthermore, demand for rehabilitation robots is increasing due to a considerable increase in the number of people suffering from disabilities and the geriatric population with more health disorders. Rehabilitation robots are divided into teleoperated robots, autonomous collaborative robots, exoskeleton robots, smart wearable mechatronic systems, hand-held robots, and social robots.¹⁸

Teleoperated robots are two synchronized robotic systems that communicate via a channel. The goal of teleoperated robots is to transfer the human operator's agency and motor control across a barrier and allow remote operation while getting sensory awareness feedback from the isolated environment.¹⁸

Autonomous collaborative robots are specifically developed to do a task that requires a high level of autonomy, situational awareness, and collaboration with human operators. The implementation of this technology includes mobility of patients with disabilities, delivering care remotely and monitoring vital signals in isolated centers, as well as interaction between isolated patients and family.¹⁸

Exoskeleton robots are externally-operated systems that humans wear for motor function, enhancing mobility capabilities, or rehabilitating a human's lost abilities and function. Exoskeleton robots can recognize configuration and assist each human joint movement.^{18,32}

Smart wearable mechatronic systems are humans wearing devices to assess body signals and provide patient information with biofeedback to support, aid, or augment the user's capacities. These technologies have been required to help improve sensory abilities in patients with disabilities.^{18,33,34} During the COVID-19 pandemic, some studies showed the use of wearable technologies to track time-series of symptoms in patients and to evaluate the progress and changes in biomarkers. Assistive mechatronic system is a solution for increasing demand of motion assistance in patients with disabilities.^{18,35}

Hand-held robots are designed to be held in a user's hand and often assist with task completion. These robots can increase the independence of patients with disabilities. An example of this robot is a smart-spoon robot that helps patients with hand tremors to eat more efficiently. During the COVID-19 pandemic, hand-held robots also can reduce physical contact between patients and caregivers or nurses.^{18,36}

Social robots have been utilized for various applications that benefit from interaction, such as language teaching, learning for senior care, and treating persons with autism and depression.¹⁸

Disinfection and Cleaning Robots

Disinfection and cleaning robots allow decontamination, sterilization, and elimination of pathogens in different environments. Generally, these robots use ultraviolet light technology, chemical spraying systems, or cleaning systems with disinfectant substances. During the COVID-19 pandemic, demand for disinfection and cleaning robots are expected to increase four to six times due to their efficiency, safety, and efficacy.^{16,37}

A study by Sierra et al reported that the desired robotic characteristics of disinfection and cleaning robots include noiselessness, user-friendliness, safety, accuracy, autonomy, and cleaning assistance. According to healthcare workers, the most important functionality of disinfection and cleaning robots was to provide cleaning assistance.¹⁷ Disinfection and cleaning robots to prevent infection was the most critical element to consider when developing the robots. This item was a top priority for both doctors and nurses, demonstrating the medical environment aspect. Infection prevention and patient safety are significant goals in the medical environment, and their importance had recently grown.^{15,17}

Delivery and Logistics Robots

Delivery and logistic robots can perform transport tasks, including for medical equipments and patients.^{38–40} The characteristics of delivery and logistic robots include its accuracy, interaction provision, distribution of medicines, monitoring function, mitigation, safety, and the provision of alert and support. The most important functionality for healthcare workers is to provide support in medical services. Delivery and logistics robots are required for healthcare workers. The study by Sierra et al reported that about 65.8% of healthcare workers agreed to promote delivery and logistic robots in their profession.¹⁷

Telemedicine and Telepresence Robots

Telemedicine and telepresence robots help patients in isolation get medical services, monitor patients' vital signs remotely, and perform patrol and awareness tasks. This category does not include surgical robots. The characteristics of telemedicine and telepresence robots include its safety, trustworthiness, accuracy, alerts and support provision, communication, and interaction.¹⁷

Limitation of the Study

This review is restricted to medical robots and only focuses on the domain mentioned in the majority of studies. Future research should include other types of medical robots, such as those used to assist in the transportation of medical supplies, prescription drug dispensing, and sanitation, as well as clinical management, to provide a more comprehensive overview.

Outlining a general and generic guideline The World Health Organization should establish a minimum standard for medical robots that can be adopted and applied in the local context. Trans regional medical robotic legislation would facilitate international collaboration on medical robot science, legal system, and ethics.

Further research should concentrate on specific medical robot services such as robotic wheelchairs and robot nursing assistants, as well as outcome measures after using medical robots, in order to improve medical robot implementation. The COVID-19 pandemic compelled us to rethink our health-care delivery systems and adaptable to evolving end user trends and needs. As a result, medical robots may no longer be considered an option, but rather the quality of medical care.

Conclusion

Robots are required by healthcare workers during the COVID-19 pandemic in order to diminish the risk of infection. The highest demands for medical robotics functionalities include cardiac measurements and oxygen saturation monitoring (medical functions); examination record delivery, video and image play, and medical information delivery functions (operational functions); the ability to recognize and avoid obstacles (movement functions); as well as disinfection and cleaning robots. Nurses and doctors had different requirements for functions and types of medical robotics. Thus, when developing medical robotics during the COVID-19 pandemic, it is important to consider who among medical staff would be the main users of the medical robots.

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Disclosure

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