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Scenario-Based Assessment of User Needs for Point-of-Care Robots

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Objectives: This study aimed to derive specific user requirements and barriers in a real medical environment to define the essential elements and functions of two types of point-of-care (POC) robot: a telepresence robot as a tool for teleconsultation, and a bedside robot to provide emotional care for patients. **Methods:** An analysis of user requirements was conducted; user needs were gathered and identified, and detailed, realistic scenarios were created. The prototype robots were demonstrated in physical environments for envisioning and evaluation. In all, three nurses and three clinicians participated as evaluators to observe the demonstrations and evaluate the robot systems. The evaluators were given a brief explanation of each scene and the robots' functionality. Four major functions of the teleconsultation robot were defined and tested in the demonstration. In addition, four major functions of the bedside robot were evaluated. **Results:** Among the desired functions for a teleconsultation robot, medical information delivery and communication had high priority. For a bedside robot, patient support, patient monitoring, and healthcare provider support were the desired functions. The evaluators reported that the teleconsultation robot can increase support from and access to specialists and resources. They mentioned that the bedside robot can improve the quality of hospital life. Problems identified in the demonstration were those of space conflict, communication errors, and safety issues. **Conclusions:** Incorporating this technology into healthcare services will enhance communication and teamwork skills across distances and thereby facilitate teamwork. However, repeated tests will be needed to evaluate and ensure improved performance.

Keywords: Robotics, Point-of-Care Systems, Remote Consultation, Needs Assessment

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I. Introduction

Telehealth is defined as the use of telecommunications to provide health information and care across distance [1]. It may improve access to specialists by redistributing expertise in given care contexts virtually [2]. The adoption of telehealth technologies greatly reduces location as a barrier to accessing high-quality treatment and care, opening up new opportunities for healthcare providers to engage with patients and other professionals across distances. In Korea, the concentration of large hospitals in urban areas causes many problems, such as inequity of access to health facilities and services, missing optimal time of treatment, and increasing health care expenditures due to unnecessary transfers and repeated laboratory tests [3,4]. Teleconsultation using telehealth technologies could solve these problems by facilitating the exchange of medical information to assist diagnosis and treatment at a distance.

In prior studies, telemedicine or teleconsultation using videoconferencing has been shown to improve access and the quality of clinical care available to rural patients. Also, it can lead to lower costs through the reduction of unnecessary transfers [5-9]. Furthermore, studies have reported that professional development opportunities and support from specialists may help improve rural medical workforce recruitment and retention [10,11]. However, most teleconsultations are asynchronously conducted, and response time is an important factor in facilitating rapid diagnosis and finding appropriate treatments for diseases in telemedicine and teleconsultation. That is, a lack of extemporaneity is a limitation of care [2,9].

In addition, the main users of these systems are healthcare providers, not patients. Patients admitted to hospitals and their unformal caregivers may be passive due to a lack of information, and they tend to become dependent on their healthcare providers. Furthermore, many inpatients feel anxiety and fear regarding upcoming treatments, but healthcare providers cannot allot enough time for emotional care. Point-of-care (POC) refers to situations in which healthcare providers deliver health services to patients at the time of care and not asynchronously [12]. This approach aims to capture the patient's healthcare needs and deliver proper treatment and care in a timely manner. Bedside terminals are currently used in point-of-care settings, generally to provide medical content or web browsing services; however, they do not sufficiently support emotional care for patients [13]. In the holistic view of healthcare, emotional needs are considered inextricable from physical and psychological needs. For this reason, we are currently developing two types of POC robots: a telepresence robot as a tool for teleconsultation, and a bedside robot for emotional care of patients.

It is critical to understand the factors that may increase acceptance and adoption of healthcare robots so that robots can be designed in such a way that they will be more likely to be adopted [14,15]. Therefore, we conducted scenario-based demonstrations to assess what users need from POC robots and to define the functions of the robots prior to system development. In this paper, we will address methodological aspects related to the development of these POC robots for healthcare and will discuss the results of implementing those approaches. The objective of this study was to derive specific user requirements and barriers in real medical environments.

II. Methods

Scenario-based assessment is an efficient method to understand the hospital environment in relation to the end needs of users, including healthcare providers, patients, and informal caregivers. We implemented an analysis of user requirements, which was a simple process encompassing four elements; (1) information gathering, (2) user needs identification. (3) envisioning and evaluation, and (4) requirements specification [16].

1. Gathering Information on the User's Context

User surveys and interviews were conducted to determine the needs of users, current work practices, and issues that need to be addressed. We also conducted field observations to gain significant information concerning the users' contexts, the equipment in use, and the place of work. To gain awareness of the drawbacks of traditional consultation through videoconferencing, we interviewed clinicians and nurses and observed the service from the user's perspective. Also, a number of hospitals have installed bedside terminals for patients; to compare existing bedside terminals, we visited hospitals that provide similar services.

2. User Needs Identification

We developed scenarios and use cases to give detailed, realistic examples of how users may carry out their tasks in specific contexts using robots. A simulated patient was defined, and the medical records of the patient were created. The developed scenario consisted of three parts, each with 3 to 4 scenes, across which the expected functions of the POC robot were mapped.

3. Envisioning and Evaluation through Scenario Simulation

Once the intended functionalities had been defined, it was important to develop a prototype to illustrate them. Feedback from evaluators could then be obtained to validate and refine the user needs. Clinicians developed, reviewed, revised, and completed the scenarios for the demonstrations. A total of 9 researchers (2 clinicians, 4 clinical nurses, and 3 system developers) were involved.

The robots tested in the demonstrations were not intended to be perfect. Imperfections such as technical errors and delays of operation are inevitable. To help reflect this reality, user responses could be assessed in both ideal and near-real cases throughout the scenario-based demonstrations. In all, 3 nurses and 3 clinicians participated as evaluators to observe the demonstrations and evaluate the robot system after they had been given a brief explanation of each scene and the robots' functions. It is necessary to conduct demonstrations of POC robots in physical environments that simulate the conditions of the work situation at a high level of realism [13]. Our scenario-based demonstrations took place in a simulation center with an emergency department, an operation room, and general wards. All the demonstrations were filmed for further evaluation.

4. Specification of Requirements

After the scenario-based demonstrations, the evaluators completed a report form, which was used to evaluate the robots and to measure their usability. The usability scale had 8 items scored on a 100-point scale. Further, unstructured interviews were conducted. Examples of prompt questions used to guide the interview included the following: "In the POC robot systems to be developed, what are the most important functions to be included?", "How does the POC robot system facilitate or obstruct patients' treatment and care when the system is integrated into a real medical environment?".

Table 1. Summary of demonstrated scenes and required functionalities

	Scene	Summary	Functionalities	Type
Scenario 1. Teleconsultation in an emergency department	1	Emergency department visit and teleconsultation request	Mobility of robot	TR
			Scanning of patient's barcode	TR
	2	Teleneurology assessment during the initial teleconsultation	Voice recognition	TR
			Image acquisition using a super-wide-angle camera	TR
	3	Implementation of teleconsultation	Communication using bidirectional video system	TR
			Laser pointer in shared screen	TR
Scenario 2. Teleconsultation in the operating room	1	Preparation of teleconsultation in the operating room	Mobility of robot	TR
			Image acquisition using a super-wide-angle camera	TR
	2	Teleconsultation during operation	Image acquisition using a high-resolution camera	TR
			Communication using bidirectional video system	TR
	3	Additional consultation of other medical departments	Point at affected area of patient	TR
			Image acquisition and close-up using a high-resolution camera	TR
			Remote control of camera angle	TR
			Image transmission and display	TR
Scenario 3. Post-operative care of the patient	1	Patient's admission to the ward	Educational video play	BR
			Voice-based intelligent scheduler	BR
			Bidirectional video call	BR
	2	Counseling of medical staff	Voice, video notes	BR
			Alarm	BR
			Image laboratory result display on the screen	BR
			Video recording in real time	BR
			Teleconsultation in real time	TR
			Remote control of camera angle	TR
	3	Meeting request of guardian	Video play	BR
			Voice, video notes	BR
	4	Hospital life of the patient	Communication start based on voice recognition	BR
			Emotion recognition based on non-verbal expression of the patient	BR

TR: teleconsultation robot, BR: bedside robot.

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III. Results

1. Gathering Information on the User's Context and User Needs Identification

1) Teleconsultation robot

Ninety participants including 39 physicians and 51 nurses were surveyed. Among the desired functional requirements for a teleconsultation robot, medical information delivery, a wireless system, and screen sharing had the highest priority in that order. The internal medicine and surgical wards, operating room, and outpatient clinic revealed greater need for such a system.

The major themes derived from the interviews included major functions, usability, expected effects, and anticipated issues. The subthemes of the major functions were communication, visual, and data-sharing functions. The subthemes of usability were movability, the form of the device, and convenience for users. The major expected effects included 'prevention of delays in treatment' and 'assistance in decision making on transferring a patient'. The major anticipated issues included 'anxiety about the robot', 'judgment error', and 'limitations in use at some divisions'.

2) Bedside robot

In all, 198 participants including 108 patients, 39 physicians, and 51 nurses were surveyed. The desired function requirements for a bedside robot included prediction of patient's events, call bells, and support for physician's rounds.

The major themes derived from the interviews included the major functions, usability, and anticipated issues. The subthemes of the major functions were patient support, patient monitoring, and healthcare provider support. The subthemes of the major functions were patient support, patient monitoring, and healthcare provider support. The subthemes of usability were the form and movement of the robot as well as methods of fixation. The subthemes of anticipated issues included 'increased workload of healthcare providers' and 'regard only as an amusement tool'.

2. Development of Scenarios for Demonstrations

According to the information gathered through the surveys and interviews, four major functions of the teleconsultation robot were defined and tested in scenario-based demonstrations: (1) image acquisition using a super-wide-angle camera and a high-resolution camera, (2) image transmission and display, (3) remote control of the robot's arms, and (4) mobility of the robot. Similarly, four major functions of the bedside robot were also evaluated: (1) bidirectional video system, (2) support system of doctor counseling, (3) voice recognition, and (4) ability to recognize non-verbal expressions of the patient. The functions of both types of robots were placed in the appropriate scenarios for them to be tested (Table 1). To evaluate these functions, prototypes of the POC robot were developed. The technical specifications of each robot are shown in Table 2.

The simulated patient was a 52-year-old female admitted to an emergency department for headache and memory impairment. Patient data for this simulated patient was derived from real patient data. Clinicians reviewed and revised draft scenarios in which the specific situation, including place and time, was defined, and each scene was explained in detail. Hospital S was defined as an on-site hospital requesting

Table 2. Technical specification of the point-of-care robots

Type of robot	Components	Specifications
Teleconsultation robot	Height	150 cm
	Weight	50 kg
	Bottom dimensions	Width 45 cm, depth 50 cm
	Max speed	2.7 km/hr if freely moving, 4.5 km/hr if controlled moving
	Movement wheel	Front-wheel drive with handle on the rear
	Collision sensors	Total 7 (3 front, 2 each on side) of collision sensors detect objects within 300 cm
	Other	Microphone, 2 types of cameras (one using a super-wide-angle camera and one using a high-resolution camera for image acquisition), 2 monitors (1,920 mm × 1,080 mm, 1,024 mm × 768 mm)
Bedside robot	Height	110 cm from the bottom
	Screen	10 inch
	Fixation methods	Fixed on the bed instead of wall or ceiling for easy installation and removal
	Mobility	Three axes of movement in total

teleconsultation, while hospital M was an off-site hospital providing teleconsultation. Examples of final scenarios are shown in Tables 3–5.

3. Envisioning and Evaluating the POC Robot System and Requirement Specification

A total of four research assistants took roles as two clinicians,

Table 3. Scenario of teleconsultation in an emergency department

Scenario 1: Teleconsultation in an emergency department

Scene 1: Emergency department visit and teleconsultation request
Place: Hospital S emergency department
Time: May 9, 2016, 10:00 AM

Abu Abudiba (52/F) visits the hospital S emergency department for headache and severe memory loss. She is examined by the emergency physician, Dr. S, and undergoes CT scanning. Dr. S detects abnormalities in the radiograph.

Dr. S brings the teleconsultation robot that was being evaluated, and clicks the robot's 'ON' button. The patient allows her wrist band to be scanned by the robot's sensor. On a touch screen monitor, Dr. S selects 'Neurology' and then clicks 'Request consultation'.

Scene 2: Teleneurology assessment during the initial teleconsultation
Place: Hospital M outpatient neurology clinic & hospital ER
Time: May 9, 2016, 10:10 AM

Dr. P, the physician on call for hospital M neurology consultation, receives an emergency text from hospital S. The message is: Consultation requested for an emergency patient. Dr. P clicks the 'Hospital S consultation' icon on the computer, and then clicks 'Accept emergency consultation request'. As Dr. P remotely controls the consultation robot, it rotates a super-wide-angle camera to transmit a live feed of the patient monitor screen at the patient's bedside.

Hospital M, Dr. P: *This is Dr. P at Neurology. Can you hear me well?*

Hospital S, Dr. S: *Yes. I can hear you well. As you can see, the patient is a 52-year-old female who has been taking medications for hypertension. Her symptoms began approximately 2 to 3 weeks prior to her visit. She had a headache on the left side of her head, with slurred speech, memory deficit, and blurry vision in the right eye. She visited the ER because the symptoms worsened abruptly on the day of her visit. A CT scan performed in the ER showed abnormalities; thus, I requested a consultation.*

Dr. P checks the patient's ER records, displayed on the monitor.

Hospital M, Dr. P: *Please hold. I will examine the CT image first.*

Scene 3: Implementation of teleconsultation
Place: Hospital M outpatient neurology clinic & hospital S ER
Time: May 9, 2016, 10:20 AM

The teleconsultation robot displays the CT screen on the monitor.

Hospital M, Dr. P: *There is a mass in the left parietal lobe. Perform an MRI.*

Dr. S prescribes an MRI and is sent the results. Dr. P clicks the "laser pointer" button on the screen and then clicks the left parietal lobe area on the MRI image.

Hospital M, Dr. P: *This is the area of the lesion. You can see midline shifting to the right, and the mass size is approximately 7 cm. The edema and hemorrhage surrounding the mass seem to indicate tumor bleeding. I suspect high-grade glioma, which should be removed operatively.*

Hospital S, Dr. S: *I see. Thank you. I will go ahead and recommend hospitalization.*

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a nurse, and a family caregiver (Figure 1). The upper left part of Figure 1 shows the evaluation of image acquisition using a super-wide angle camera, and the upper right part shows the function of the mobility of the robots. The lower left part of Figure 1 shows communication using a bidirectional video system. In the lower right part, the patient and her family caregiver watch educational video contents.

The scores for the usability of the POC robots are shown in Table 6. After the demonstrations, the participants, including scenario developers, research assistants, and observers discussed the results informally. The evaluators reported that both types of POC robots were acceptable, and the problems identified based on the demonstrations were those of space conflict, communication errors, and safety issues (Table 7).

Table 4. Scenario of teleconsultation in an operating room

Scenario 2: Teleconsultation in the operating room
Scene 1: Preparation of teleconsultation in the operating room Place: Hospital S OR Time: May 14, 2016, 1:00 PM The patient enters the operating room. As a frozen biopsy is expected during tumor removal, Dr. M, the neurosurgeon, requests hospital M pathology consultation. He selects 'Pathology' on the monitor, and clicks 'Request consultation'; the hospital M pathologist receives the consultation request through a text message, clicks the 'hospital S consultation' icon on the computer, and then clicks 'Accept consultation request'. Dr. M, the neurosurgeon at hospital S, sends a message to Dr. P at hospital M through the robot where surgery has begun. The patient is in prone position, and the nurse manually moves the teleconsultation robot to a position where it will not contaminate the surgical area. Dr. P at hospital M remotely manipulates the viewing angles of the super-wide-angle camera and high-resolution camera. Hospital M, Dr. P: *I will adjust the camera angle to get a better surgical field of view.*
Scene 2: Teleconsultation during operation Place: Hospital S OR Time: May 14, 2016, 2:00 PM During surgery, the two physicians discuss and select the area for biopsy using the zoom-in and pointer functions of the robot. Frozen biopsies are obtained from four areas. Hospital S, Dr. M: *We will obtain four frozen biopsies, from the superior, medial, lateral, and inferior margins.* The specimens are sent to the pathology laboratory. The pathologist at hospital S sends images of the frozen biopsy sections to the pathology laboratory of hospital M. The pathologist at hospital M receives a notification of new information, and then examines the images and sends the results to hospital S. The robot in the hospital S OR displays the received biopsy results on its screen. Hospital M, Dr. P: *As we suspected, the frozen biopsy results indicate high-grade glioma. The samples from the superior and medial margins are positive.* Hospital S, Dr. M: *(Observing the results on the robot screen) Oh, I see that.* Hospital M, Dr. P: *You would have to remove slightly more.* .... Dr. P at hospital M zooms in on the surgery footage displayed on the monitor. Hospital M, Dr. P: *Will you be able to remove more tumor tissues below the op bed? It seems difficult to distinguish normal tissue from tumor tissue. What do you think?* Hospital S, Dr. M: *I think there is a risk of touching the motor tract if I proceed further medially.* Hospital M, Dr. P: *Yes. I agree that further resection is considerably risky. You should end the operation here. I think most of the tumor tissues have been removed. We should observe the patient's progress.*

Table 5. Scenario of post-operative care of the patient

Scenario 3: Post-operative care of the patient
Scene 1: Patient's admission to the ward Place: Hospital S patient ward Time: May 14, 2016, 6:00 PM The patient enters the ward after a postoperative CT scan. The nurse plays a video about postoperative precautions on the bedside robot for the caregiver to watch. A video call request from Dr. M is shown on the bedside robot. Hospital S, Dr. M: *How are you doing? Fortunately, the surgery went well. Removal was considerably difficult because the tumor was deeply seated. We removed as much tumor tissue as possible. In the postoperative CT scan, the midline of the brain that was shifted to the right because of the tumor is now mostly corrected. The surgery was successful; however, we will have to observe her progress.* Dr. M displays the rounds schedule for the patient on the bedside robot's monitor.
Scene 4: Hospital life of the patient Place: Hospital S patient ward Time: May 20, 2016, 8:40 AM The patient wakes up in the morning. Patient: *Furo (the robot's name)!* Bedside robot: *Good morning, Abu Abudiba. What can I do for you?* Patient: *Tell me my schedule for today.* The screen turns on automatically and displays the day's schedule. The robot informs the patient as follows: Bedside robot: *Sure. I will tell you about today's schedule. You will have your morning medications at 8:10. The rounds are scheduled to begin at 9….* Time: May 20, 2016, 2:00 PM The patient is lying down on her bed, looking bored. She is not sleeping. The robot recognizes the patient's state and proactively recommends fun media content. Bedside robot: *Abu Abudiba, are you not feeling well? Should I show you a few fun games or TV programs?* Patient: *No, I would like to read news online.* Bedside robot: *Sure. What type of news would you like to read? Domestic news, finance, politics, lifestyle, or entertainment?*

IV. Discussion

Evaluating prototypes in an actual hospital is not allowed due to patient safety and privacy issues. Hence, system developers often face difficulties in representing user requirements in an appropriate form [16]. In this study, the POC robot systems were assessed through user requirement analysis based on scenario-based demonstrations. This allowed the evaluation of multiple functions and the identification of use strategies before their actual implementation in the medical field.

We found that it was feasible to use the teleconsultation robot for difficult cases. Consultations were conducted in real time, and it was possible to request additional information and assess patients directly. This is important because the quality of treatment and care are strongly influenced by proper timing [2,9]. The teleconsultation robot has two types of cameras for image acquisition, a super-wide-angle camera

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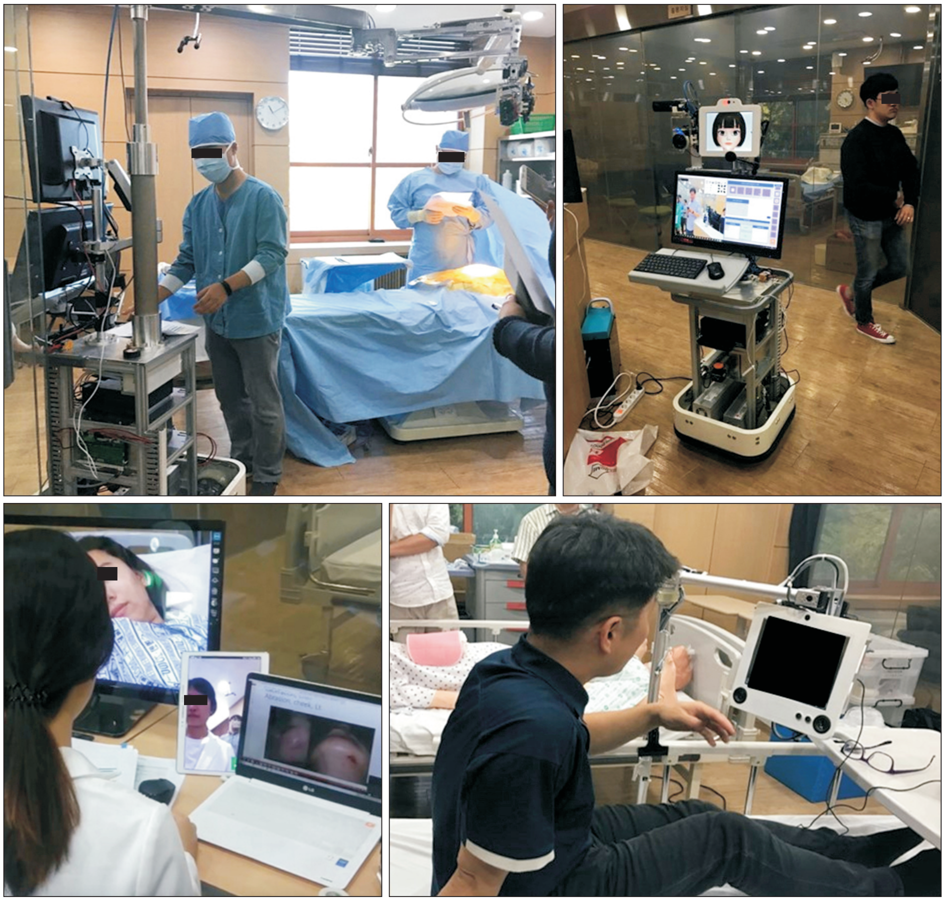

Figure 1. Scenario-based demonstrations of the point-of-care robots.

Table 6. Usability of the point-of-care robot after scenario-based assessment (n = 6)

Items	Value
Teleconsultation robot	
Evaluate the usefulness of the teleconsultation robot.	63.3 ± 19.4
Evaluate the ease of use of the teleconsultation robot.	57.5 ± 14.1
What was the expected score for the teleconsultation robot?	70.0 ± 11.0
What is the actual evaluation score of the teleconsultation robot?	56.7 ± 16.3
Bedside robot	
Evaluate the usefulness of the bedside robot.	66.7 ± 17.5
Evaluate the ease of use of the bedside robot.	69.2 ± 17.4
What was the expected score for the bedside robot?	74.2 ± 11.1
What is the actual evaluation score of the bedside robot?	47.5 ± 27.2

Values are presented as mean ± standard deviation.

and a high-resolution camera. This is essential for participation in distant events; it gives distant healthcare providers a closer look at not only the patient's critical areas but also the surrounding environment for consultation and educational purposes.

Several evaluators mentioned that another benefit of using the teleconsultation robot was that it allowed continual learning and accumulation of experience under the instruction of specialists. Wang et al. [9] pointed out that hospitals that provide consultation and education should be more proactive in regularly scheduling online teaching rounds, consultations on difficult cases, and other types of diversified tele-education activities to provide access to ongoing medical, educational, and training support.

One of the drawbacks of the implementation was space conflict with other medical devices and healthcare providers. When robots are used in operating rooms it is crucial to maintain sterility and patient safety, meaning that the robots must have bigger, heavier bodies to allow stable fixation. On the other hand, in general wards, a slim form would be appropriate to aid functions such as person tracking or autonomous navigation function. Accordingly, we are considering developing two different types of teleconsultation robots

Table 7. Expected benefits and challenges of the point-of-care robot

	Teleconsultation robot	Bedside robot
Benefits	Increased support from and access to specialists and their resources Local access to continuing education and professional development Increased skills or knowledge through multi-disciplinary clinical case discussions	Support healthcare provider and enhance efficiency of point-of-care Improve quality of hospital life Patients and informal caregivers as partners in care
Challenges	Communication errors between on-site and off-site staff due to the lack of clinical data Mobility of the robot considering safety issues Security of a clear view considering space conflict Uncoordinated movement of the robot's manipulators Space conflict with other medical devices and healthcare providers Movement of the patient that can cause accidental collisions Loss of sterility	High error rates in voice recognition when people speak simultaneously Fixation methods considering patients' safety and emergency situation Uncertain effects of emotional care through face or gesture recognition system

separately for use in operating rooms and general wards.

In these assessments, the physicians used PC-based programs to provide consultation; however, in real-world medical environments, it is not easy to sit in front of a PC in all situations. In this respect, it is important for health professionals to use tablet PCs or smartphones in teleconsultations. A language translation function should also be considered to allow teleconsultation with practitioners in other countries. Additional use of peripherals, such as electronic stethoscopes and radio frequency identification (RFID) can be considered as well.

Various types of bedside terminals are already in use, and bedside robots also need differentiation in the point-of-care aspect. Healthcare providers can share test results or view diagnostic images with a patient during staff rounds so that patients and informal caregivers can serve as partners in care. The patient can record the staff rounds and reproduce them as many times as desired so that physicians and nurses do not need to repeat the same explanations. Voice commands using activation phrases enable patients with limited physical ability to control the robot without touch, turning it on and off, calling their nurse, or playing educational videos or entertainment options. In this way the bedside robot is expected to play a major role in raising patient satisfaction and enhancing healthcare productivity.

Among the various functions evaluated, a major one was care through face or gesture recognition. The robot not only operates passively according to the user's commands but also starts conversations based on recognition of the patient's condition. When the patient wakes up, the bedside robot recognizes this and wishes the patient good morning. Then, based on the scheduled surgery or procedure, the robot recommends educational content, for instance. Existing bedside terminals are designed to perform simple tasks or to be used purely for entertainment; however, as robot capability increases, personal use will encompass a greater variety of tasks and more complex social functions [13]. The social capability of the robot may indeed critically influence its acceptance, as variables such as social intelligence, emotion expression, and nonverbal social cues may influence user expectations about the robot's social capability [17]. Incorporating this function into bedside robots will not only improve patients' quality of hospital life but also support POC service provision.

In the scenario-based assessment, evaluators indicated errors in voice recognition when more than one user spoke at the same time. In the active state, surrounding noise should be technically filtered, and only the voice of the nearest user should be recognized. Evaluators also emphasized that the method of fixation is very important, because the robot should be removable easily and quickly in an emergency.

The present study had some limitations. First, subjective assessments were obtained through self-report methods. Therefore, an objective scale should be used for measurement to improve validity in repeated evaluations. Second, the results may have been biased because of the small num-

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ber of evaluators. Third, the prototypes of the robots were immature; hence, further research must be undertaken that reevaluate and improve the robots.

While there remain challenges, incorporating this technology into healthcare services will enhance information-sharing across distances and thus will facilitate teamwork. Repeated evaluations will be needed to ensure improvement in performance.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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