The Purpose of Bedside Robots

Exploring the Needs of Inpatients and Healthcare Professionals

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Robotic systems are used to support inpatients and healthcare professionals and to improve the efficiency and quality of nursing. There is a lack of scientific literature on how applied robotic systems can be used to support inpatients. This study uses surveys and focus group interviews to identify the necessary aspects and functions of bedside robots for inpatients. A total of 90 healthcare professionals and 108 inpatients completed the questionnaire, and four physicians and five nurses participated in the focus group interviews. The most highly desired functionalities were related to patient care and monitoring, including alerting staff, measuring vital signs, and sensing falls. Nurses and physicians reported different needs for human-robot interaction. Nurses valued robotic functions such as nonverbal expression recognition, automatic movement, content suggestion, and emotional expressions. The results of the patients' open-ended questions and healthcare professionals' focus groups indicate that the purpose of the robots should primarily be treatment and nursing. Participants believe bedside robots would be helpful but have concerns regarding safety and utility. This study attempts to determine which aspects of robots may increase their acceptance. Our findings suggest that if robots are used in healthcare institutions, they may improve the effectiveness of care.

KEY WORDS: Artificial intelligence, Inpatients, Needs assessment, Point-of-care systems, Robotics

With the development of information and communication technology comes the increasing use of robots in healthcare. Scholars expect that eventually artificial intelligence (AI) will be used to support healthcare professionals and to improve the efficiency of medical treatment and nursing.[1] While AI is sometimes used in homes and long-term care facilities, few studies have examined how this technology can be used within the hospital environment. For example, using human-robot interaction (HRI) with inpatient bedside terminals may provide patients with better emotional support and allow them to be more proactive during their hospital stay.

Point of care (POC) is defined as the timely provision of medical services to a patient.[2] This approach prioritizes quick determination of a patient's needs and proper care and nursing. These needs can be either physical or emotional; the two are inseparable, according to the holistic view of nursing.[3] For example, inpatients and their guardians often feel anxiety or fear due to the lack of information regarding a patient's condition and/or expected treatment. This may cause them to become more passive or dependent on hospital staff; however, healthcare professionals often find it difficult to devote enough time to providing patients with the necessary emotional support. To rectify this, several healthcare institutions, both in Korea and overseas, have introduced tablet PC-type bedside terminals to provide inpatients with portal and better POC services.[4,5] Although the detailed functions vary by system, these portals typically provide medical information, Web access, and TV services.[6]

However, despite the growing use of such systems, there is a lack of scientific literature on how applied robotic systems can be used to support inpatients. Before AI is better integrated into healthcare, research must consider a diverse range of factors to aid users' acceptance and use of robots. This necessitates conducting research on users' needs to better understand such systems' requirements and functions,[7,8] as well as viewpoints of healthcare professionals, since they understand the environment in which the robots will be operating.[9] To this end, this study used surveys and focus group interviews to identify the necessary aspects and functions of bedside robots for inpatients, thereby providing basic data for constructing actual AI systems and evaluating their effectiveness.

METHODS

In this study, a survey was conducted to collect data on the needs of inpatients and healthcare professionals, better understand how bedside robots could fill these needs, and identify issues in implementing such technology. The researchers first conducted online surveys to collect quantitative data and

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followed these up with focus group interviews to collect qualitative data.[10] The online survey and interviews received approval from the institutional review board of the Seoul National University Hospital (H-1607-174-779).

Participants

The selection criteria for survey respondents were based on convenience sampling. All respondents were adult males and females who agreed to participate in the survey. They were either healthcare professionals (ie, physicians and nurses) or currently admitted hospital inpatients. The survey period was October to November 2016.

Survey respondents were recruited through a bulletin board notice titled "Call for Research Participants" posted in a university hospital in Korea. The notice asked people to visit a given Web link with additional instructions, and those who agreed to participate were invited to complete the survey. There were 315 surveys logged; incomplete and insincere responses were excluded, resulting in a total of 198 respondents (90 healthcare professionals and 108 inpatients).

The researchers then selected participants for the focus group interviews using snowball sampling. All respondents were healthcare professionals currently employed by healthcare institutions. The participants were divided into two groups, physicians (four individuals) and nurses (five individuals), and attended two sets of interviews in September and October 2016.

Quantitative Data

The initial online questionnaire, developed by researchers in healthcare and nursing informatics, contained 40 questions related to bedside robots' essential features and functions (Table 1).[5,11,12] To verify the survey's validity, six experts, including professors in medical and nursing informatics, reviewed its contents and construction. In addition, the researchers distributed a preliminary questionnaire to 10 graduate students in nursing informatics, and the final questionnaire was revised to address their comments on the survey's readability.

Respondents were asked how important they felt the following functions of bedside robots to be: measurement and monitoring, alarm and warning, educational and consultation support, entertainment and convenience, user interface, HRI, and safety features (Table 1). Responses were measured using a 4-point Likert scale ranging from "not important at all" (1) to "very important" (4). For inpatients, the online questionnaire also included open-ended questions about the advantages and limitations of bedside robots.

Prior to the online survey, participants viewed a short, approximately 2-minute video explaining the bedside robot (Figure 1). They could access questionnaires either through quick response (QR) codes or typing in the URL and were able to complete the survey at any time or place, thereby ensuring privacy and honesty. Only participants who agreed to the instructions were invited to complete the survey. If someone tried to take the survey twice, he/she received a message indicating that the questionnaire was already completed, thus blocking access to the questionnaire response page and preventing duplicate responses. The questionnaire was administered using the online survey site SurveyMonkey (SurveyMonkey, San Mateo, CA; https://ko.surveymonkey.com).

Results were processed using IBM SPSS Statistics version 22.0 (IBM, Armonk, NY). Questionnaire items related to the bedside robots' essential elements and functions were analyzed using constants, percentages, means, and standard deviations. A t test was used to analyze the different needs of healthcare professionals and inpatients as well as of physicians and nurses.

Qualitative Data

The researchers then collected qualitative data through focus group interviews. All participating healthcare professionals provided consent to participate, and they were presented with structured open-ended questions regarding their needs and the possible issues when instituting a bedside robot system.

Prior to the interviews, participants viewed a short, approximately 2-minute video explaining the bedside robot (Figure 1). Each group interview was 60 to 90 minutes long and ended once the conversation no longer yielded new ideas or opinions (saturation of themes). Each focus group was recorded in its entirety, with the researchers writing additional memos when necessary. In order to remove bias and improve the reliability and validity of the results, a team consisting of two or more researchers, including the moderator and research assistants in charge of field notes, attended the interviews, allowing for researcher triangulation.[13] Interview questions were based on previous research[5,14–16] and included the following open-ended items:

- What do you expect to happen if bedside robots are developed and applied?
- How do you think bedside robots will help patients?
- How do you think bedside robots will help healthcare professionals?
- What external form should the bedside robot have?
- What are the possible administrative problems with a bedside robot?
- What are the possible clinical problems with a bedside robot?
- What are the possible barriers to using bedside robots in the present situation?

The researchers then transcribed all recordings and marked meaningful words and sentences, which were then categorized based on similar concepts. These data were then reviewed to determine similarities and differences as well as meanings and structures. In this manner, the researchers were able to identify what healthcare professionals believed to be the essential functions of and expected issues with bedside robots.

Table 1. Questionnaire Categories

	Categories	No. of Items	Examples
1	Measurement and monitoring	8	Continuous monitoring of blood pressure
			Access to vital sign data
			Feedback on activity level
2	Alarm, warning	7	Call bell
			Fall detection
			Posture recognition
3	Education, consultation, and support	4	Consultation support: x-rays and computed tomography scans at the patient's bedside
			Educational resource (eg, tips for a healthy lifestyle)
4	Entertainment and convenience	6	Real-time menu selections
			Internet access
5	User interface	6	Touchscreen
			Frequently used functions
6	HRI	7	Context-aware interaction (eg, "It is time for dinner. Enjoy your meal.")
			Voice recognition (in case it is difficult for users to use touchscreen)
			Ability to recognize nonverbal expressions (ie, recognize emotion from a patient's facial expression)
7	Safety-related features	2	Collision avoidance (ie, sensor to prevent collision)
			Antimicrobial material
Total no. of items		40	

For analysis, answers to the open-ended questions from the questionnaire for the inpatients were categorized after gaining a complete understanding of them through repeated reading.

Results

Survey Participants

A total of 90 healthcare professionals and 108 inpatients completed the questionnaire. Of the 90 healthcare professionals, 43.3% were physicians, and 56.7% were nurses; 65.6% were females, and the mean age was 32 ± 6.5 years. Physicians had a variety of specialties, including respiratory medicine and surgery, and the nurses also worked in various departments, such as the ICU, internal medicine ward, and emergency room. Of the 108 inpatients who participated, 57.4% were females, and mean age was 44.1 ± 15.0 years. They were admitted to various departments, including digestive internal medicine, hematology, and oncology (Table 2).

Differences Between Inpatients and Healthcare Professionals

The 10 uses or traits of bedside robots ranked most important by both inpatients and healthcare professionals were as follows (in order from most important to least important): emergency alerts, calling nurses, taking vital signs, monitoring blood pressure, monitoring heart rate, detecting falls,

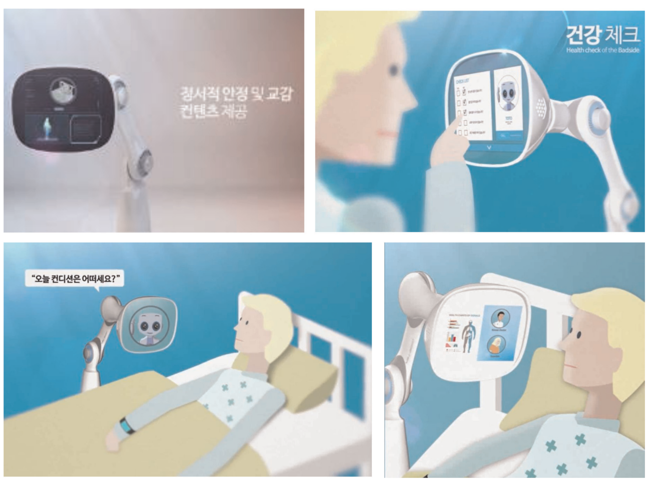

FIGURE 1. Screenshots of video clips used.

Table 2. Survey Participants

Type		n	%
Healthcare professionals (n = 90)			
Gender	Male	31	34.4
	Female	59	65.6
Age (y)	Mean ± SD	32.0 ± 6.5	
Position	Physician	39	43.3
	Nurse	51	56.7
Specialty (physicians only)	Respiratory	5	12.82
	Surgery	5	12.82
	Plastic surgery	4	10.26
	Family medicine	3	7.69
	Pediatrics	3	7.69
	Neurology	2	5.13
	Emergency medicine	2	5.13
	Rehabilitation medicine	2	5.13
	Orthopedics	2	5.13
	Other	11	28.16
Departments (nurses only, duplicate responses accepted)	ICU	13	23.21
	Internal medicine	11	19.64
	Emergency room	7	12.5
	Surgery	6	10.71
	Pediatrics	4	7.14
	Outpatient	3	5.36
	Other	7	21.44
Inpatients (n = 108)			
Gender	Male	46	42.6
	Female	62	57.4
Age (y)	Mean ± SD	44.1 ± 15.0	
Departments (top 5)	Gastroenterology	9	8.3
	Hemato-oncology	7	6.5
	Respiratory	7	6.5
	Neurology	7	6.5
	General surgery	6	5.6

made of an antimicrobial material, providing consultation support for viewing medical records, measuring oxygen saturation, and taking patients' temperature.

In most cases, healthcare professionals scored these items higher than inpatients did. Items with statistically significant differences included taking vital signs ($P = .001$), detecting falls ($P < .001$), measuring oxygen saturation ($P < .001$), having a zoomable screen ($P = .039$), having a touchscreen ($P = .023$), having a camera ($P < .001$), recognizing posture ($P < .001$), transmitting text ($P = .001$), and serving as an educational resource ($P < .001$), all of which showed a higher demand from healthcare professionals than inpatients (Table 3).

Differences Between Nurses and Physicians

Nurses generally reported a higher need for bedside robots than physicians. This included statistically significant differences in the need for emergency alerts ($P = .002$), taking vital signs ($P = .008$), providing consultation support for viewing medical records ($P = .024$), measuring oxygen saturation ($P = .011$), including voice recognition ($P = .002$), including manual movement control ($P = .006$), including a list of favorite functions ($P = .043$), recognizing patient posture ($P = .012$), serving as an educational resource ($P = .026$), recognizing nonverbal expressions ($P < .001$), moving automatically ($P = .004$), providing content suggestions for patient preferences ($P = .020$), and being able to make emotional expressions ($P = .031$) (Table 3).

Healthcare Professionals' Focus Groups

The thematic analysis of the focus group interviews with five nurses and four physicians yielded four themes: functions for assessment of patients, convenience for patients and healthcare professionals, shape and movement, and expected issues.

Functions for Assessment of Patients

Interviewees agreed that the most important function of robots was the ability to assist in patient treatment and support their safety. In particular, they considered that monitoring patient safety and predicting events, such as accidents (ie, falls) and pressure ulcers, which can prolong patients' stays and lead to death or injury, would be quite helpful. One respondent remarked:

> *What if we use [the robot] as a tool to enhance patient safety? Falls and pressure ulcers are factors that evaluate the quality of nursing. Nurses cannot continuously keep an eye on at-risk patients; therefore, if there were alarms telling us to change the postures of patients at risk of pressure ulcers or sense the risk of falls, it would be quite helpful.*

Other participants mentioned the usefulness of display screens that provide notifications when a patient is in pain or send a photo and video to a patient's electronic medical record.

Functions for Convenience for Patients and Healthcare Professionals

Other common desires for bedside robots were the ability to help patient support functions, such as wayfinding (ie, helping patients reach check-up rooms and notifying them of appointments), notifying patients of drug dosing and meal times, and other tools to help patients live independent lives while at the hospital. Medical professionals who worked in ICUs and isolation rooms mentioned the utility of functions, such as video-assisted visits that help family members visit patients without the risk of infections and video recording of medical rounds or treatment requiring repetitive education. Others hoped that the robots could support healthcare professionals' work by explaining medicines, test results, real-time diet selection, and task reminders. For example, one respondent remarked:

Table 3. Functional Priority of Bedside Robots

	Functionality	Total (n = 198)	Pts (n = 108)	HCP (n = 90)	Difference (Pts vs HCP)	RN (n = 51)	PHY (n = 39)	Difference (RN vs PHY)
		Mean ± SD	Mean ± SD		t	Mean ± SD		t
1	Alerting in case of emergency	3.51 ± 0.55	3.52 ± 0.54	3.51 ± 0.55	−0.096	3.67 ± 0.48	3.31 ± 0.57	3.256[a]
2	Calling nurses	3.44 ± 0.65	3.40 ± 0.67	3.44 ± 0.64	0.495	3.43 ± 0.70	3.46 ± 0.55	−0.221
3	Verification of vital signs	3.37 ± 0.55	3.26 ± 0.52	3.51 ± 0.57	3.240[a]	3.65 ± 0.48	3.33 ± 0.62	2.697[a]
4	Blood pressure monitor	3.31 ± 0.56	3.27 ± 0.52	3.36 ± 0.61	1.071	3.45 ± 0.64	3.23 ± 0.54	1.729
5	Heart rate monitor	3.28 ± 0.62	3.20 ± 0.61	3.38 ± 0.63	1.976	3.45 ± 0.67	3.28 ± 0.56	1.268
6	Fall detection	3.28 ± 0.70	3.11 ± 0.74	3.48 ± 0.58	3.810[b]	3.57 ± 0.54	3.36 ± 0.63	1.703
7	Made of antimicrobial material	3.27 ± 0.62	3.30 ± 0.66	3.23 ± 0.58	−0.706	3.31 ± 0.55	3.13 ± 0.61	1.510
8	Consultation support: medical records	3.21 ± 0.65	3.19 ± 0.66	3.22 ± 0.63	0.300	3.35 ± 0.56	3.05 ± 0.69	2.297[a]
9	Measure oxygen saturation	3.20 ± 0.64	3.04 ± 0.67	3.40 ± 0.56	4.099[b]	3.53 ± 0.54	3.23 ± 0.54	2.601[a]
10	Measure body temperature	3.20 ± 0.59	3.17 ± 0.57	3.23 ± 0.62	0.787	3.29 ± 0.67	3.15 ± 0.54	1.098
11	Consultation support: image (ie, computed tomography, x-ray)	3.20 ± 0.68	3.16 ± 0.73	3.24 ± 0.62	0.895	3.35 ± 0.56	3.05 ± 0.69	1.915
12	Collision avoidance (sensor)	3.19 ± 0.61	3.16 ± 0.61	3.23 ± 0.60	0.875	3.33 ± 0.48	3.10 ± 0.72	1.830
13	Voice recognition	3.14 ± 0.64	3.19 ± 0.60	3.11 ± 0.66	−0.827	3.08 ± 0.52	2.95 ± 0.79	3.256[a]
14	Text size control	3.12 ± 0.66	3.07 ± 0.72	3.18 ± 0.57	1.106	3.27 ± 0.53	3.05 ± 0.60	1.859
15	Treatment schedule notification (ie, drug administration)	3.11 ± 0.64	3.09 ± 0.68	3.16 ± 0.56	0.704	3.20 ± 0.60	3.10 ± 0.50	0.785
16	Volume control	3.11 ± 0.62	3.05 ± 0.65	3.19 ± 0.58	1.620	3.27 ± 0.53	3.08 ± 0.62	1.620
17	Screen zoom	3.05 ± 0.69	2.96 ± 0.75	3.17 ± 0.60	2.079[a]	3.24 ± 0.62	3.08 ± 0.58	1.236
18	Measuring pain	3.05 ± 0.71	3.02 ± 0.75	3.11 ± 0.63	0.933	3.22 ± 0.61	2.97 ± 0.63	1.836
19	Touchscreen	3.02 ± 0.77	2.91 ± 0.80	3.16 ± 0.70	2.291[a]	3.18 ± 0.68	3.13 ± 0.73	0.884
20	Camera	2.98 ± 0.83	2.74 ± 0.93	3.27 ± 0.58	4.858[b]	3.31 ± 0.58	3.21 ± 0.57	0.884
21	Manual movement control	2.97 ± 0.63	2.95 ± 0.68	3.02 ± 0.54	0.790	3.16 ± 0.42	2.85 ± 0.63	2.807[a]
22	Favorite functions list	2.96 ± 0.65	2.92 ± 0.67	3.02 ± 0.62	1.142	3.14 ± 0.53	2.87 ± 0.70	2.057[a]
23	Patient posture recognition	2.95 ± 0.71	2.80 ± 0.71	3.17 ± 0.64	3.829[b]	3.31 ± 0.62	2.97 ± 0.63	2.568[a]
24	Text transmission	2.93 ± 0.72	2.79 ± 0.81	3.11 ± 0.55	3.228[a]	3.14 ± 0.53	3.08 ± 0.58	0.514
25	Educational resources	2.89 ± 0.77	2.61 ± 0.77	3.26 ± 0.57	6.739[b]	3.10 ± 0.55	3.37 ± 0.56	2.270[a]
26	Activity level feedback	2.84 ± 0.66	2.85 ± 0.71	2.86 ± 0.61	0.039	2.92 ± 0.59	2.77 ± 0.63	1.176
27	Hospital overview	2.84 ± 0.77	2.80 ± 0.77	2.89 ± 0.77	0.842	3.00 ± 0.75	2.74 ± 0.79	1.577
28	Real-time diet/menu	2.82 ± 0.74	2.87 ± 0.82	2.76 ± 0.62	−1.117	2.75 ± 0.66	2.77 ± 0.58	−0.181
29	Nonverbal expression recognition	2.81 ± 0.71	2.78 ± 0.77	2.86 ± 0.63	0.785	3.08 ± 0.52	2.56 ± 0.64	4.081[b]
30	Internet access	2.78 ± 0.81	2.73 ± 0.86	2.84 ± 0.73	0.997	2.90 ± 0.70	2.77 ± 0.78	0.850
31	Automatic movement	2.77 ± 0.74	2.73 ± 0.79	2.82 ± 0.68	0.867	3.00 ± 0.63	2.59 ± 0.68	2.930[a]
32	Content suggestions	2.71 ± 0.74	2.69 ± 0.79	2.73 ± 0.68	0.366	2.88 ± 0.62	2.54 ± 0.72	2.381[a]
33	Method of contact (ie, phone, email)	2.60 ± 0.78	2.56 ± 0.86	2.66 ± 0.67	0.919	2.65 ± 0.59	2.67 ± 0.77	−0.136
34	Emotional expressions	2.54 ± 0.80	2.49 ± 0.86	2.60 ± 0.73	0.967	2.75 ± 0.66	2.41 ± 0.79	2.198[a]
35	Modifiable character	2.54 ± 0.78	2.56 ± 0.76	2.50 ± 0.81	−0.578	2.59 ± 0.80	2.38 ± 0.81	1.183

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Table 3. Functional Priority of Bedside Robots *(Continued)*

	Functionality	Total (n = 198)	Pts (n = 108)	HCP (n = 90)	Difference (Pts vs HCP)	RN (n = 51)	PHY (n = 39)	Difference (RN vs PHY)
		Mean ± SD	Mean ± SD		t	Mean ± SD		t
36	TV	2.52 ± 0.74	2.51 ± 0.79	2.53 ± 0.67	0.228	2.59 ± 0.64	2.46 ± 0.72	0.883
37	Everyday responses (ie, "Good morning")	2.50 ± 0.79	2.43 ± 0.81	2.59 ± 0.75	1.458	2.59 ± 0.75	2.59 ± 0.75	−0.009
38	News	2.49 ± 0.72	2.54 ± 0.80	2.44 ± 0.60	−0.927	2.49 ± 0.58	2.38 ± 0.63	0.823
39	Radio	2.37 ± 0.77	2.31 ± 0.85	2.44 ± 0.66	1.299	2.47 ± 0.58	2.41 ± 0.75	0.416
40	Movies	2.35 ± 0.74	2.35 ± 0.84	2.36 ± 0.62	0.036	2.41 ± 0.61	2.28 ± 0.65	0.977

Abbreviations: HCP, healthcare professionals; PHY, physicians; Pts, patients.
[a] $P < .05$.
[b] $P < .01$.

Informing and educating patients is one of the important tasks of a nurse, and patients often do not understand immediately. For example, if all relevant information is provided to a patient waiting for an examination at once—for instance, examination time, location of the examination room, preparation procedure, examination procedure, and precautions after the examination—the patient may not understand everything, as he/she is already quite nervous due to the upcoming examination. Therefore, it would be nice if the robot provided these explanations, in a kind manner, over and over again. The patient can then see this information whenever he/she wants, and the robot will not grow tired just like a nurse would.

Robots' Shape and Movement

Interview participants provided conflicting opinions on robots' shape and movement. One said that if the robots were portable and not attached to a bed or wall, they could be attached to a wheelchair to act as a navigation device or to a walker to encourage ambulation. However, others pointed out that if the robots were detachable, there would be a risk of losing them. Moreover, this could cause safety risks if the robots were to collide with a patient.

One participant noted that the robots should be able to fold up against a ceiling or wall or be easily removed in an emergency when not in use in order not to interfere with treatment or nursing, which might keep them from being accepted by medical professionals. Most participants agreed that there should be some flexibility in movement, allowing users to move the monitor freely.

However, respondents were ambivalent about whether patients would wish the robots to express identity or emotions through automatic movement. They felt that this could make boring hospital life more enjoyable, but it could also lead to anxiety. Respondents remarked as follows:

If the initial rapport is built well, [the robot] would be something like a friend during the lonely hospital life. It should implement motions, expressions, and voices that patients like. A patient needs to find the robot comfortable. It should be intuitive to use and should not interfere with or annoy the patient. In particular, if the robot moves or talks unexpectedly, the patient may feel anxiety. I wonder if this human-robot interaction will help adult patients. They may find it interesting in the beginning but grow tired of it if its responses are not diverse enough.

No matter how efficient we are, there is a limit to how much emotional care we can provide because one nurse takes care of many patients. We feel sorry for patients in such a case. I think it would be helpful if the robot can share certain emotions with patients. It would be important to see how naturally the robot reacts to the voices and actions of patients.

Expected Issues

Participants noted that there is a risk that the robots could become a tool for simple enjoyment rather than medical care. They believed that if the robots did not have unique functions different from the monitor-type bedside terminals in larger Korean hospitals, it would be difficult for patients to differentiate between them. One participant remarked:

> *I think there is a possibility that the bedside robot will become a simple TV rather than being used for medical use. If the robots have functions already adequately provided by existing bedside terminals, users may feel that they are simply more difficult to use and not use them at all. There must be unique functions specifically performed by these robots in order for them to survive in today's market.*

Another participant noted that these robots could actually increase the workload of healthcare professionals, since they would have to educate patients on how to use robots and take care of their frequent breakdowns and maintenance. The majority were also concerned about privacy issues and possible data leaks from attached cameras.

Finally, participants emphasized that the most important aspect in designing both robots' form and movement was patient safety. As patients are often susceptible to infections, the materials with which the robots are made should be resistant to infection and easy to disinfect. In addition, many believed that there should be sensors to avoid patient collision.

Inpatients' Open-Ended Responses

Patients taking the online survey were also asked open-ended questions on bedside robots' potential benefits and limitations; 75 patients responded to the questions. These responses were categorized into expectations about utility, questions and concerns about safety and utility, need for comfortable user interface and user experience (UI/UX) with core functionality, need for personalized functions and services, preferences for healthcare professionals over robots, and concerns about increases in the price of healthcare (Table 4).

DISCUSSION

Core Elements of Bedside Robots

The results of this study yielded key information on the functions, advantages, and limitations of bedside robots. The results showed that the most highly desired functionalities for both healthcare professionals and patients were related to patient care and monitoring, including alerting staff of emergencies, measuring and confirming vital signs, and sensing and predicting falls. In addition, the results showed that healthcare professionals had significantly higher needs for robots that assisted in various medical tasks, including measuring vital signs, detecting falls, measuring oxygen saturation, video recording, recognizing posture, and providing patients with educational resources.

These results were consistent with those of previous studies, which found that nurses expected medical robots to take over their tasks or provide support for their work. For example, Lee et al[17] examined nurses' need for care robots in five Korean hospitals and found that nurses desired robots that could undertake the following primary roles: "measuring/monitoring," "mobility/activity," and "safety care." Likewise, Mundher and Zhong[18] used state-of-the-art technology, such as Kinect sensors, to construct a smart system that monitored elderly patients and sent alarms when dangerous situations, such as falls, occurred. They found that these robots could be helpful in nursing tasks as they could track users and engage in real-time detection. The present study differs from those described above because it focuses on inpatients' use of robots rather than nurses. However, the results of this study make clear that patients expect the robots to perform similar roles. In other words, this AI can be used to help in treatment, the point of hospital admission, supporting staff and patients in functions related to care and monitoring.

The results of the patients' open-ended questions and healthcare professionals' focus groups indicate similar outcomes; both groups agree that the purpose of the robots should primarily be treatment and nursing. Not only does this differentiate these robots from the terminals already in place in some hospitals, but also focusing the robots' role on patient treatment could improve patients' and healthcare professionals' acceptance of them and increase their utilization. For example, other studies have found that the utilization of AI is improved if users believe it to be beneficial to their most necessary tasks.[19,20] As such, it is very important to integrate users' needs into the development of bedside robots.[21] In this case, both inpatients and healthcare professionals asserted that they wanted the robots to be simple and easy to manage, focusing on a few core functions rather than being able to help with a diverse array of tasks. This has the additional benefit of making the robot simpler, leading to less frequent breakdowns and maintenance, which could lower the robots' reliability and increase nurses' workload.

Human-Robot Interactions

Neither patients nor healthcare professionals prioritized HRI. This may be due to people's lack of experience in interacting with robots, which makes it difficult for them to evaluate its importance. In addition, this is consistent with the findings of previous studies. For example, Lee and Kim[22] found that robots' "communication" role is often least expected and that people often question the robots' ability to accurately interpret complex emotions.

The present study also found that nurses and physicians had different needs for HRI. In comparison to physicians, nurses were more likely to value robot functions, such as nonverbal expression recognition, automatic movement, content suggestions based on patients' preferences, and emotional expressions. In other words, nurses valued HRI more. This may be because nurses have more need for HRI to alleviate

Table 4. Patients' Expectations of and Concerns Regarding Bedside Robots (N = 75)

Categories	n (%)	Sample Response
Expectations of robot's utility	23 (30.7)	Useful to communicate with healthcare professionals
		Quite helpful for patients with limited mobility through voice support
		Quick and accurate perceptions of patient information will help in treatment and nursing
User-friendly UI/UX with core functionality	14 (18.7)	No need to include functions covered by tablet PC; need to consider priorities rather than number of functions
		Elderly patients should be able to use it easily and intuitively
Concerns regarding safety and utility	8 (10.7)	May be bulky and difficult to control
		Need to consider risks to patients from malfunctions
Concerns about increases in healthcare costs	8 (10.7)	Should be cheap and available for everyone
		Concerned that bedside robots would lead to increased healthcare costs
Personalized functions and services	6 (8.0)	Emotional expressions should change depending on patient's age
		Convenient to have individualized schedules and notifications, as well as individual care
Preference for healthcare professionals over robots	4 (5.3)	Robots would be far behind in emotional care, although they would be convenient
		Healthcare professionals should do everything except for simple functions
Potential to reduce human resources	3 (4.0)	Robots may replace some tasks performed by the healthcare professionals, leading to job loss
Other	9 (12.0)	Patients' individual memoirs and/or messages of hope could be displayed on the robots

some of the demand for the direct care that they provide. However, future studies are required to verify this claim.

During focus group discussions in this study, nurses asserted the need for building human-robot rapport so that the robots could provide emotional care and help patients have a positive hospital experience. Despite the robots' beneficial roles, patients will not accept them if they find their interactions uncomfortable. In other words, for healthcare robots to be successfully accepted by users, AI must have the following three elements: meet patients' basic motive for use; adequate ease of use; and physical, cognitive, and emotional comfort.[8,23]

Existing studies have confirmed that ease of use has a major impact on user acceptance.[20,24] Some studies have reported that older adult users will reject a robot if they are unfamiliar with the technology,[25] but others report that users with less technological experience will still accept AI if they are useful and easy to use.[26] As such, bedside robots require an intuitive user interface that can be used by inexperienced users. In the hospital environment, where there are many older individuals, functions, such as larger buttons, a clear voice, and highly visible screens, are quite important.[27]

The bedside robot in the present study was not humanoid; the video that participants viewed prior to the survey and interviews showed "robots" that were faces displayed on a tablet screen. Vlachos et al[28] conducted research on preferences regarding robots' shape and found that users preferred robots with a touchscreen, the ability to make eye contact, and the ability to talk to users directly. Robots such as the one used in this study, shown as faces on a screen, may still express facial expressions and images, thereby appearing less aggressive and friendlier than those with a more human form.[29]

De Ruyter et al[30] developed a list of socialization behavior characteristics, allowing robots to be programmed with seeming social skills, such as cooperation, empathy, proactivity, self-control, responsibility, and trust. Examples include seeming to listen by looking at the user and nodding, interacting with a smile, remembering individual details about the user and using his/her name, using facial expressions, and admitting to errors. Studies report that programming robots with social skills makes users feel that the robots actually exist, ultimately improving their acceptance.[20] Likewise, McColl[31] developed and deployed robot systems that perceive a user's emotional state based on facial expressions and that then respond appropriately. The results indicate that robots that engage in emotional recognition are considered to have social intelligence and that the user's recognition of the robot's nonverbal cues can influence acceptance.

Other studies found that users preferred to be able to talk to robots and that they are interested in conversations about both healthcare and the robot itself.[27] Kim et al[32] evaluated older adults' acceptance of AI and found differences depending on the level of perceived social interactions. It appears that older adult users recognize an interactive agent not only as a tool for achieving tasks but also as a target with which one can interact. Robots' social ability provides enjoyment for users and provides them with an incentive to use the robots.[20,24] Moreover, users' perceived enjoyment is an important factor of robots' usability and ease of use.[20,33] As such, it is important that bedside robots meet users' expectations regarding social skills.

User Concerns

Inpatients' responses to the open-ended questions indicate that they believe bedside robots would be helpful. However, they were concerned about impediments if its functions are not implemented appropriately. In addition, the responses reveal participants' need to receive direct medical care from healthcare professionals and questions on whether robots can actually help treatment or support patients during hospital stays.

Such findings are consistent with the results of previous studies. For example, Lee et al[17] found that while nurses were receptive to care robots, they were concerned about malfunctioning or hindering nurses' rapport with patients. Another study, in which robots were used to measure 57 patients' blood pressure and which then asked patients about their perceptions of robots, found that patients had positive or negative perceptions, depending on patients' media exposure to robots.[34]

While patients feel that medical robots are useful when performing simple tasks, they are often concerned about reliability and safety.[34] Moreover, the speed and direction of robots' movements and actions can increase users' anxiety or sense of threat and may appear to be offensive or disturbing.[35,36] Therefore, patients' perceptions of and emotions toward robots differ, depending on their psychosocial variables, previous experience with robots, and the environment in which robots are used. Further research must consider how to develop robots with high acceptance rates, since patients' perception of robots is an important factor in their acceptance.

CONCLUSION

There is a growing interest in the application of robots in the nursing and healthcare sectors, and researchers generally agree that robots can help in various nursing tasks.[1] However, few hospitals have actually implemented such AI due to the "tech-resistance" of healthcare professionals and healthcare institutions.[37] For example, nurses tend to believe that robots have an inadequate ability to care for patients.[38] Moreover, they fear that the utilization of robots would complicate and increase their workload.[17]

Despite these fears, the researchers find themselves in an era where active discussions of IT usage in nursing, including robots, are vital. As such, this study attempts to determine how both healthcare professionals and patients feel about robots and which aspects of robots may increase their acceptance. In addition, it evaluates whether robot care can be applied in the hospital environment to help inpatients and provide them a positive hospital experience. The findings in this study suggest that if robots were to be used in healthcare institutions, they could improve the effectiveness of care. Unlike healthcare professionals, they do not grow tired and can respond to patient and staff requests at any time.[17,18] Moreover, they can enable accurate and real-time monitoring and alert nurses of dangerous situations, thereby improving clinical results and quality of care.

Despite these significant findings, this study has several limitations. First, the survey was conducted in a single university hospital. As the environment, the severity of patients' conditions, and the purpose of admission may differ depending on the size of the hospital, further research is needed to analyze the demand for robots in healthcare institutions of various sizes. Moreover, the demand for robots may differ depending on the characteristics of both healthcare professionals and patients. As this study was unable to analyze the differences in demand stemming from these variables, future studies are recommended to assess demand according to the age, gender, department, and assigned wards of healthcare professionals, as well as according to the severity, condition, and type of treatment received by patients.

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References

1. Erikson H, Salzmann-Erikson M. Future challenges of robotics and artificial intelligence in nursing: what can we learn from monsters in popular culture? *The Permanente Journal*. 2016;20(3): 127–129.
2. Ebell M. Information at the point of care: answering clinical questions. *Journal of American Board of Family Medicine*. 1999;12: 225–235.
3. McQueen AC. Emotional intelligence in nursing work. *Journal of Advanced Nursing*. 2004;47(1): 101–108.
4. Yen PY, Walker DM, Smith JMG, Zhou MP , Menser TL, McAlearney AS. Usability evaluation of a commercial inpatient portal. *International Journal of Medical Informatics*. 2018;110: 10–18.
5. Yoo S, Lee KH, Baek H, et al. Development and user research of a smart bedside station system toward patient-centered healthcare system. *Journal of Medical Systems*. 2015;39(9): 86.
6. Baird AH. The new Royal Adelaide Hospital: the age of the digital hospital dawns in South Australia. In: *Proceedings of the Sixth Australasian Workshop on Health Informatics and Knowledge Management*. Vol. 142. Adelaide, Australia: Australian Computer Society; 2013.
7. Beer JM, Prakash A, Mitzner TL, Rogers WA. Understanding robot acceptance. 2011. https://smartech.gatech.edu/bitstream/handle/1853/39672/HFA-TR-1103-RobotAcceptance.pdf. Accessed August 22, 2018.
8. Broadbent E, Stafford R, MacDonald B. Acceptance of healthcare robots for the older population: review and future directions. *International Journal of Social Robotics*. 2009;1(4): 319.
9. Deneke J, Lehane D, Kandler A, Menchini T, Laaksoharju M, Obaid M. Using rapid prototyping to explore design implications for a pill-dispensing social agent. In: *The Proceedings of the 5th International Conference on Human Agent Interaction*. Bielefeld, Germany: Association for Computing Machinery; 2017.

10. Stewart DW, Shamdasani PN. *Focus Groups: Theory and Practice*. Thousand Oaks, CA: Sage Publications; 2014: 2014.

11. Dale Ø, Boysen ES, Svagård I. One size does not fit all. In: *Proceedings of the International Conference on Computers Helping People With Special Needs*. Linz, Austria: Springer; 2016.

12. Kilian J. Method and mobile device for automatic activation of applications: Google patents. 2012. https://patents.google.com/patent/US20110230209A1/en. Accessed August 22, 2018.

13. Speziale HS, Streubert HJ, Carpenter DR. *Qualitative Research in Nursing: Advancing the Humanistic Imperative*. Philadelphia, PA: Lippincott Williams & Wilkins; 2011.

14. Khan Z, Interaction and Presentation Laboratory. In: *Attitudes Towards Intelligent Service Robots*. Stockholm, Sweden; 1998.

15. Shore JH. Telepsychiatry: videoconferencing in the delivery of psychiatric care. *The American Journal of Psychiatry*. 2013;170(3): 256–262.

16. Copleston S, Bugmann G. Personal robot user expectations. In: *Technical Report 08-01, Robotics and Intelligent Systems*. Plymouth, UK: University of Plymouth; 2008:230.

17. Lee JY, Song YA, Jung JY, et al. Nurses' needs for care robots in integrated nursing care services. *Journal of Advanced Nursing*. 2018;74: 2094–2105.

18. Mundher ZA, Zhong J. A real-time fall detection system in elderly care using mobile robot and kinect sensor. *International Journal of Materials, Mechanics and Manufacturing*. 2014;2(2): 133–138.

19. De Graaf MM, Allouch SB, Klamer T. Sharing a life with Harvey: exploring the acceptance of and relationship-building with a social robot. *Computers in Human Behavior*. 2015;43: 1–14.

20. Heerink M, Kröse B, Evers V, Wielinga B. Assessing acceptance of assistive social agent technology by older adults: the Almere model. *International Journal of Social Robotics*. 2010;2(4): 361–375.

21. Whelan S, Murphy K, Barrett E, Krusche C, Santorelli A, Casey D. Factors affecting the acceptability of social robots by older adults including people with dementia or cognitive impairment: a literature review. *International Journal of Social Robotics*. 2018: e26.

22. Lee HS, Kim J. Scenario-based assessment of user needs for point-of-care robots. *Healthcare Informatics Research*. 2018;24(1): 12–21.

23. Hancock PA, Billings DR, Schaefer KE, Chen JY, de Visser EJ, Parasuraman R. A meta-analysis of factors affecting trust in human-robot interaction. *Human Factors*. 2011;53(5): 517–527.

24. Sun H, Zhang P . Causal relationships between perceived enjoyment and perceived ease of use: an alternative approach. *Journal of the Association for Information Systems*. 2006;7(9): 24.

25. Czaja SJ, Charness N, Fisk AD, et al. Factors predicting the use of technology: findings from the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and Aging*. 2006;21(2): 333.

26. Di Nuovo A, Broz F, Wang N, et al. The multi-modal interface of Robot-Era multi-robot services tailored for the elderly. *Intelligent Service Robotics*. 2018;11(1): 109–126.

27. Goher K, Mansouri N, Fadlallah S. Assessment of personal care and medical robots from older adults' perspective. *Robotics and Biomimetics*. 2017;4(1): 5.

28. Vlachos E, Jochum E, Demers LP . The effects of exposure to different social robots on attitudes toward preferences. *Interaction Studies*. 2017;17(3): 390–404.

29. Hosseini SMF, Hilliger S, Barnes J, Jeon M, Park CH, Howard AM. Love at first sight: mere exposure to robot appearance leaves impressions similar to interactions with physical robots. *Lisbon, Portugal: IEEE*. 2017.

30. De Ruyter B, Saini P , Markopoulos P , van Breemen A. Assessing the effects of building social intelligence in a robotic interface for the home. *Interacting With Computers*. 2005;17(5): 522–541.

31. McColl D. *Affective Body Language Detection and Generation for Socially Assistive Robots*. Toronto, ON, Canada: University of Toronto; 2015.

32. Kim M, You NK, Kim Y, Hahn S, Yun MH. Effects of ICT ability of the elderly people for the acceptability of conversational agent. In: *The Proceedings of the Conference of Ergonomics Society of Korea*. Jeju, Korea: Ergonomics Society of Korea; 2017.

33. Park E, Kwon SJ. The adoption of teaching assistant robots: a technology acceptance model approach. *Program*. 2016;50(4): 354–366.

34. Broadbent E, Kuo IH, Lee YI, et al. Attitudes and reactions to a healthcare robot. *Telemedicine Journal and E-Health*. 2010;16(5): 608–613.

35. Hiroi Y, Ito A. *Are Bigger Robots Scary? The Relationship Between Robot Size and Psychological threat*. Xian, China: IEEE; 2008.

36. Dautenhahn K. Socially intelligent robots: dimensions of human-robot interaction. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*. 2007;362(1480): 679–704.

37. Salzmann-Erikson M, Eriksson H. Tech-resistance: the complexity of implementing nursing robots in healthcare workplaces. *Contemporary Nurse*. 2016;52(5): 567.

38. Bettinelli M, Lei Y, Beane M, Mackey C, Liesching TN. Does robotic telerounding enhance nurse-physician collaboration satisfaction about care decisions? *Telemedicine Journal and E-Health*. 2015;21(8): 637–643.