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ORIGINAL ARTICLE

Telehealth, remote monitoring and consultations

Cardiology professionals' views of social robots in augmenting heart failure patient care

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Aims Social robots are arriving to the modern healthcare system. Whether patients with heart failure, a prevalent chronic disease with high health and human costs would derive benefit from a social robot intervention has not been investigated empirically. Diverse healthcare provider's perspectives are needed to develop an acceptable and feasible social robot intervention to be adopted for the clinical benefit of patients with heart failure. Using a qualitative research design, this study investigated healthcare providers' perspectives of social robot use in heart failure patient care.

Methods and results Interdisciplinary healthcare providers from a tertiary care cardiac hospital completed a structured individual interview and a supplemental questionnaire. The framework method was used to analyse the qualitative data. Respondents ($n = 22$; saturation was reached with this sample; 77% female; 52% physicians) were open to using social robots to augment their practice, particularly with collecting pertinent data and providing patient and family education and self-management prompts, but with limited responsibility for direct patient care. Prior to implementation, providers required robust evidence of: value-added beyond current remote patient monitoring devices, patient and healthcare provider partnerships, streamlined integration into existing practice, and capability of supporting precision medicine goals. Respondents were concerned that social robots did not address and masked broader systemic issues of healthcare access and equity.

Conclusion The adoption of social robots is a viable option to assist in the care of patients with heart failure, albeit in a restricted capacity. The results inform the development of a social robotic intervention for patients with heart failure, including improving social robot efficiencies and increasing their uptake, while protecting patients' and providers' best interest.

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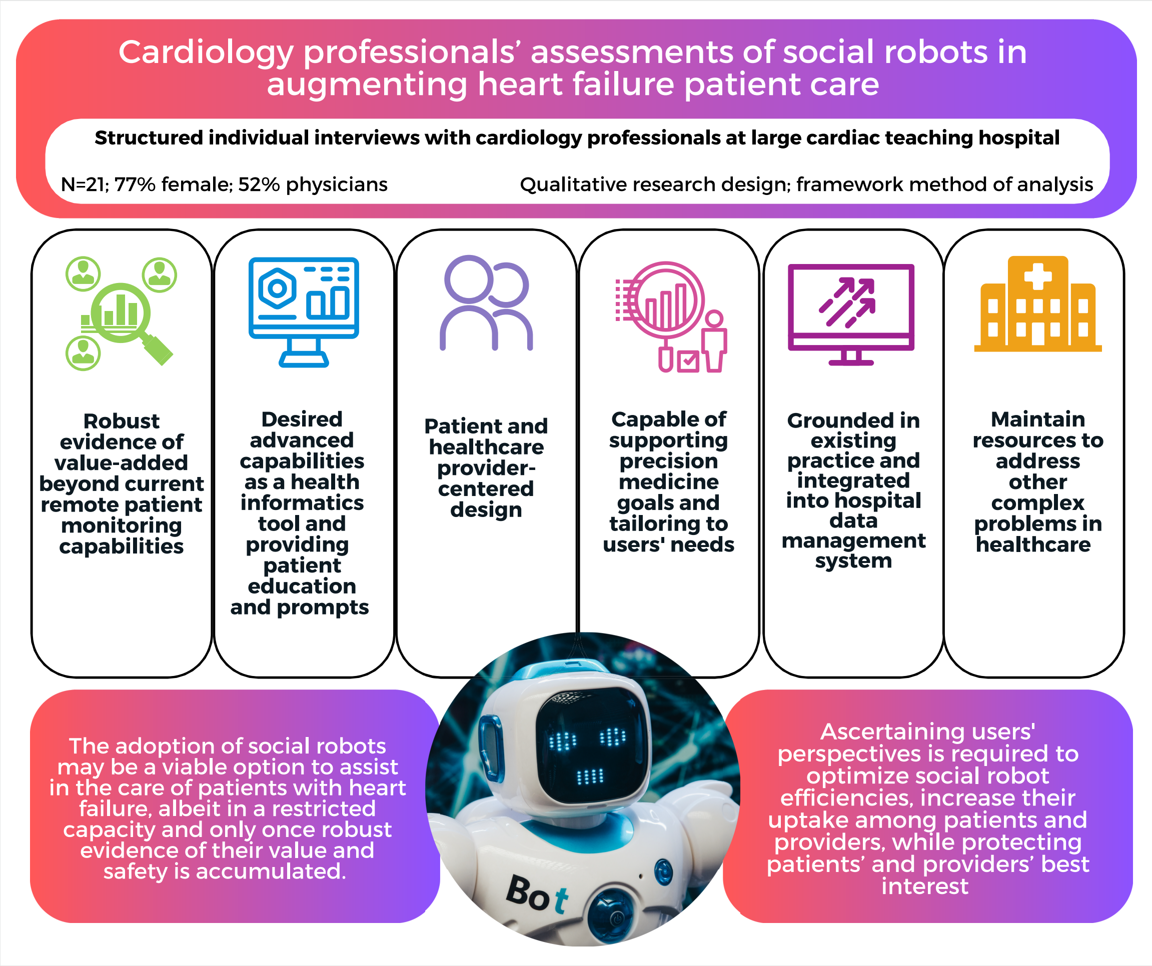
Graphical Abstract



Keywords Social robots • Virtual care • Heart failure • Cardiology • Health technology • Socially assistive robots

Introduction

Social robots in healthcare

Social robots are arriving to the modern healthcare system, particularly to supplement gerontological services and those with cognitive impairment.[1] Social robots are defined as artificial agents embodied with human or animal features that actively communicate and coordinate with humans through verbal, non-verbal, or affective modalities.[2] They can be equipped with artificial intelligence technology that allows the system to mimic some aspects of human to human encounters, such as recognizing voices, providing eye contact, interpreting and responding appropriately to verbal and non-verbal cues, and adapting to the user's feedback. Embedded technology can facilitate the remote monitoring of patients' physiological and psychological health, aid with activities of daily living, provide rehabilitation services, and offer companionship.[3] Accumulating data supports the utility of social robots in healthcare, particularly the effects of social robots on surrogate outcomes in older individuals, such as preventative health behaviours and physiological parameters used as a proxy for measuring risk. For example, increased adherence to exercise regimes, improved medication compliance, reductions in snack episodes, weight loss, and decreased loneliness have been observed across research trials, albeit with small sample sizes and with only select non-humanoid and humanoid social robots (e.g. Paro, Nao).[4] Social robot interventions have also been linked to reduced pulse rate, saliva cortisol, systolic and diastolic blood pressure, and galvanic skin response, as well as improved oxygenation levels.[5] High-quality evidence on the efficacy of social robots on individual clinical endpoints however, is lacking,[1] and significant limitations in extant research exist,[5,6] requiring caution with the interpretation of results. For example, interventions are typically brief in duration, lack follow-up measurements, enrol a small number of participants with high levels of drop out, and evidence is of low to moderate quality. In addition, there continues to be a lack of diversity in the conditions studied, with most research focused on articulating outcomes in paediatric (e.g. children with autism spectrum disorders)[7] and geriatric (e.g. patients with dementia)[8] samples, as well as healthy community-based populations,[1,6] rendering it difficult to generalize findings to patients with heart failure.

Heart failure patient care

The burden of heart failure is rising rapidly; currently 6.2 million Americans live with the disease,[9] and it remains the most common reason for hospitalization in patients over 65 years of age.[10] The clinical course of heart failure is unpredictable, but overall, it is a progressive and life-limiting disease that is associated with a high burden of physical and emotional symptoms, resulting in poor quality of life, high levels of dependency, use of ambulatory care, and up to 50% mortality rates within 5 years of diagnosis in advanced cases.[11] The medical management of heart failure varies based on its severity and underlying cause, but typically involves lifestyle changes, pharmacotherapy, and ongoing follow-up by a cardiologist and other members of the healthcare team (e.g. dietician, physical therapists, and pharmacists). Specifically, clinical staff provide patients with medical assessments (e.g. blood pressure monitoring and physical exams), personalized testing, strategies for symptom and self-management, assistance with managing medication, and ongoing patient and family education about the disease. Due to limitations imposed by the disease and that only one in four patients with heart failure have access to home care support services, patients typically require high levels of support from family caregivers. Prevalence of psychological distress, burnout, and a reduced quality of life in family caregivers is pervasive. Unfortunately, the COVID-19 pandemic prompted significant changes to the management of patients with heart failure, including increased reliance on family caregivers, use of virtual visits and delivery of home-based healthcare services, reductions in onsite testing, laboratory services, and cardiac rehabilitation, delays in elective procedures, and an increased reluctance for onsite visits due to the risk of exposure.

Social robots in heart failure patient care

Preliminary evidence supports the use of social robots as a promising method to assist patients in confronting the challenges associated with aging and/or specific chronic diseases. It is possible, therefore, that social robots could be expected to also be an asset in addressing the patient and system-level burden associated with heart failure. This is particularly in light of system changes brought about by the COVID-19 pandemic and now extending into the post-pandemic setting. Furthermore, social robots could be leveraged to assist with caregiving processes,[6] which could potentially lessen the burden experienced by caregivers, particularly within elderly populations. It is possible that social robots, when applied in a heart failure context, could supplement in-person services/exams or tasks normally performed by a caregiver and act as a conduit for information and education. In addition, the 'social' capabilities of social robots could be leveraged to increase rapport, provide companionship, or even emotional support to the patient navigating the complexities of heart failure.

Unfortunately, research on the use of social robots in heart failure is underdeveloped. To date, only one experimental study has been conducted in a sample of patients with cardiovascular disease interacting with a social robot.[12] Higher exercise and cardiac rehabilitation adherence were observed among patients enrolled in a social robot intervention ($n = 3$) versus usual care. These outcomes were not registered, and it is unclear how representative the small sample size of patients ($n = 6$) who experienced an acute coronary syndrome and/or coronary revascularization in the context of an onsite hospital-based rehabilitative therapy program was. In a small preliminary pilot study[13] of patients in cardiac rehabilitation ($n = 4$), there was some evidence of acceptability and feasibility in the two patients exposed to four social robot sessions. Two additional studies assessed participants' attitudes and acceptance of social robots after interacting with a robot as part of a cardiac rehabilitation program.[14,15] Broadly, the results indicated that patients and clinicians had positive thoughts regarding the usefulness, utility, safety, and trust of the robot. It is unknown whether patients with heart failure would derive similar benefit from a social robot interaction or whether these patients would be accepting of such technologies in augmenting their care.

Healthcare providers' perspectives of social robots in heart failure patient care

For the successful implementation of these technologies, healthcare providers must be willing and active participants. To date, however, healthcare providers' perspectives on the integration of such technologies to support patients with heart failure are uninvestigated. Research on cardiovascular professionals' perspectives of more traditional forms of virtual care and monitoring, such as consultations via telephone or video and wearable technologies, indicates that there is a high usage of and interest in virtual care to augment traditional care[16] but that providers also report lower confidence in remote compared to in-person assessments. Providers also demonstrate concern that remote consultations and assessments would compromise patient–physician relationships,[17] which may translate into missed opportunities for clinical care, particularly for those with complex medical histories and needs. Social robots differ from existing virtual care systems as they can be imbued, to some extent, with social and emotional intelligence and could be designed to act as a data collection tool, medical assistant, and social companion within an embodied agent. Research on providers' perspectives of social robots, to date, has been centred on perceptions of healthcare workers in long-term care settings.[18] Existing reviews note that while social robots can be designed to support providers' social and physical tasks, providers were concerned that their usage would lead to a new set of problems (e.g. increasing work load, compromising patient safety and security) that would require strategies for mitigation.[18]

The current study

Considering the potential for increased responsibility placed on healthcare providers for the integration of social robots within virtual care programming for patients with heart failure, healthcare providers' perspectives must be ascertained prior to implementation. Therefore, the purpose of this study was to elicit the views of healthcare providers who provide direct care to patients with heart failure on the acceptability of social robots. This study is the first phase of a larger program of research that aims to develop a relevant, acceptable, feasible, and scientifically informed social robotic intervention that derives clinical benefit among patients with heart failure. Subsequent phases of the research will involve investigating patients' and informal caregivers' perspectives, social robot system development/modification, preliminary testing, efficacy trials, and effectiveness research.

Methods

Using a qualitative research design, this study investigated healthcare providers' perspectives of the integration of social robots to augment heart failure patient care. The study was conducted at an academic teaching tertiary cardiac hospital—the largest cardiovascular care centre in Canada. The hospital serves a large catchment area that includes central Ottawa and surrounding urban and rural communities, covering 17 000 square kilometres and serving ∼1 300 000 residents [15% rural; 16% > 65 years of age; 19% visible minority (ethnicity); median yearly after-tax household income = $69 852]. Institutional approval to conduct this investigation was received. Healthcare providers were purposively recruited to reflect a wide range in clinical roles. The final sample size was determined by quota purposive sampling criteria (i.e. obtaining at least two healthcare providers from each role) and through achieving data saturation (i.e. when accumulating data does not produce additional insights). This sample size is sufficient when looking for disconfirming evidence or trying to achieve maximum variation among a purposive sample of participants commenting on a homogenous topic. Healthcare providers fulfilling the quota criteria were contacted, via email, by the senior author to obtain interest in participating;

the research coordinator on the project (J.A.) obtained informed consent. To augment the qualitative interviews and provide detailed information about the sample, participants were asked to complete a sociodemographic questionnaire and a healthcare provider-piloted questionnaire (see Supplementary material online, *File SA*) that ascertained participants' baseline awareness and previous interactions with social robots using a 4-item (aware to not aware) or dichotomous (yes/no) scale, respectively. The questionnaire items were developed by the research team based on recommendations from members of the Brain-Heart Unified Solution through Interdisciplinary Research in Smart Technology (BHURST)—an international research consortium comprised of 15 world-leading investigators and industry innovators with extensive backgrounds in heart failure, social and cognitive robotics, human–robot interaction, and mental health. Participants were then asked to watch short videos (see Supplementary material online, *File SB*) profiling current social robots used in healthcare. Individual structured interviews were then performed with the first (K.B.) or fifth author (J.A.). All interviews were conducted and recorded online using the Zoom or Microsoft Team platforms. The interview guide (see Supplementary material online, *File SC*) was developed by the research team based on BHURST team members' recommendations and content profiled in a previous publication on social robot uses in cardiovascular medicine.[19] The guide was subsequently pilot tested with a healthcare provider with 7 years of cardiovascular clinical experience. Only the audio was retained from the video files and was transcribed verbatim in preparation for the analysis. Immediately following the interview and viewing of social robot video clips, participants completed a questionnaire in which they indicated their acceptability of social robots and general perceived usefulness and importance using a four-item Likert scale (agree to disagree; very important to not important; see Supplementary material online, *File SA*). Participants also ranked the three most useful and least useful capabilities from a 24-item list developed in consensus by members of BHURST. The study funder was not involved in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the paper for publication.

Data analysis

The Framework Method,[20] a pragmatic, flexible, and rigorous approach to managing and interpreting qualitative data, was conducted in the following steps: (i) assign codes (i.e. researcher-generated labels that summarize or condense important concepts, processes, attributes, and values) to a subset of the data (five randomly selected interviews) line-by-line; (ii) group similar codes into a provisional set of descriptive categories (i.e. analytical framework); (iii) apply the analytical framework to subsequent transcripts, noting concepts that were not captured in the existing framework; (iv) adapt the framework to accommodate emergent concepts and apply to the analysis of remaining data; (v) summarize categories, subsuming codes, code descriptions, and illustrative quotes from each participant in a framework matrix; and (vi) interpret the patterns, key characteristics, and range of data captured within the categories, represented as 'themes.' The first author conducted all analyses; the senior author served as an auditor in the analysis (i.e. reviewed the transcripts and provided feedback on the analytical framework, theme development, and selection of quotes over the course of three meetings). The first author has several years of qualitative coding experience and has investigated the role of social robots in heart failure patient care for 2 years. Her background is in Education and Health Psychology but was involved in several meetings with BHURST investigators, including K.D. who is a senior researcher and internationally renowned in social robotics. To supplement the qualitative data, describe the sample, and participants' baseline (pre-video exposure) and follow-up perspectives (post-video exposure) of social robots, descriptive analyses were conducted. Continuous variables are reported as means and categorical variables as percentages. Please see Supplementary material online, *File SD* for responses to the COREQ guidelines for reporting qualitative research.

Results

The study sample consisted of 22 healthcare providers [90% response rate; mean (M) age = 49.5; 77% female; 77% White; 13% South Asian], representing various disciplines (cardiology [$n = 7$], nursing [$n = 4$], mental health [$n = 3$], cardiology residency [$n = 2$], health services management [$n = 2$], physiotherapy [$n = 2$], and cardiac rehabilitation physicians [$n = 2$]) spanning a wide range of clinical experience [M years = 13.3; range (R) = 1–38 years]. Over half (54%) of participants were not aware of social robots prior to the study and no participants had ever interacted with a social robot. The majority of the sample agreed (29%) or somewhat agreed (57%) that social robots could be useful for patients managing heart failure. Similarly, 19% agreed and 62% somewhat agreed that social robots could support healthcare providers in optimizing heart failure patients' care. Participants noted the potential roles and benefits that social robots could have on their practice and patients' outcomes, but alongside, highlighted several limitations that would need to be addressed before implementation. The social robot capabilities deemed most useful for patients with heart failure included: detecting falls, medication reminders, and scheduling appointments. The lowest ranked capabilities were: providing oral and nasal swabs, counselling, or administering oral or intravenous medications. The qualitative portion of the study yielded 12.7 h of interview audio data (M interview time = 35.1 min), resulting in 174 single-spaced transcribed pages (M pages = 8.5). *Table 1* and the graphical abstract display the factors that healthcare providers deemed as important considerations for the implementation of social robots in heart failure patient care. Each theme is supported by two representative quotations from participants (*Table 1*).

Healthcare providers were generally optimistic about the integration of social robots, particularly as a health informatics tool or to provide education to and/or prompt patients and family members for optimizing self-monitoring and management. There was a predominant focus on the physical or informational functionalities of the social robots, while the 'social' aspects were comparatively less acknowledged. Providers were hesitant to adopt social robots in their current form or if they were responsible for direct patient care. Providers' reluctance stemmed from the perceived lack of evidence supporting their use and the potential for missing nuances in changes in patients' health status that would be better captured by an in-person encounter. Robust clinical trials indicating their effectiveness over and above existing remote patient monitoring devices, including their safety, were desired: providers were steadfast that interventions should be grounded in patient and healthcare providers' experiences and needs. The capability of social robots to tailor disease management strategies to individual patients was cited as an important priority, noting that a non-precision medicine approach would be limitedly effective and potentially hazardous to patients with heart failure, who have complex medical histories and needs. It was noted that the implementation of social robotics into routine patient care could produce additional burden on healthcare providers and overextend an already stretched healthcare system. To mitigate this risk, participants reported that social robot interventions would need to be grounded in existing practice, with requisite staffing, support, and security structures established prior to implementation. Lastly, providers were cautious about diverting valuable resources to the development and deployment of social robots, as this could potentially reroute attention away from complex health-related problems that social robots may not be capable of fully addressing. For example, investing in social robotics was deemed as a potential 'band-aid' solution that potentially masks broader systemic issues of healthcare access, inequities in care, elder patient loneliness, and staff shortages.

Discussion

This research described the results from a qualitative study measuring healthcare providers' perspectives of the integration of social robots in heart failure patient care—the first study to do so in the scientific literature. This early-phase research is required to justify and guide practices for the optimization of social robot interventions for this patient population. Collectively, the data attest that the adoption of social robots is a potentially acceptable option to assist in the collection of data and

Table 1 Considerations for social robot integration into heart failure patient care

Theme	Example participant quotations
(1) Robust evidence of value-added beyond current remote patient monitoring capabilities	You have to show proof of concept that it actually works and that it is better than what we already have. I am intrigued, but unless you show me data that it's easy to use, it's reliable, its dependable, and the patients like it, and it can be used to change outcomes, I would not invest any money in it right now. I think that it has potential, but it needs to be rigorously studied in the context of a trial, a research study, and compared to devices we already use.
	A lot of the functionalities are already easily and readily available using non-social robot technology. I am more about how we can leverage what we already have. But if there was a very robust randomized controlled trial, with a large population, that showed that hard outcomes like mortality benefit or decreased hospitalization, at the very least something to say that patients felt safe and that there were not errors in care, that patient satisfaction is high, then maybe I could be convinced.
(2) Advanced capabilities in data collection, collation, and transmission	I would say certainly as a data collection and transmitter assistant, I think it's a great idea… That hopefully it's a bit of a passive thing that does not put patients at risk. The direct stuff I'd be a bit wary of…I'm not sure I'd want a robot taking my blood or giving an intravenous injection. But I think gathering information, asking questions, and engaging responses make very good sense to me.
	It [social robot] could be programmed to provide a simple readout, like, fluids, salt restriction, weight, current medications, blood pressure, and heart rate. These are the trends for the past 2–3 weeks. The patient's principal symptom concerns are 1, 2, 3. It automatically just allows me to use the bulk of the time I have with the patient just to be dedicated on a human level and completely efficient.
(3) Potential for educating and/or prompting patients and family members on strategies for self-monitoring and self-management	I think they could be very, very appealing and not necessarily to provide a social contact but provide the assurance that that that one is being cared for and that these are the steps we are going to take in your care…If you are a single person living alone in a semi-isolated situation, I think these would be invaluable for keeping you on track and teaching you ways to track and potentially manage your symptoms.
	With heart failure there's so many varying factors that can contribute to it, you know? You have got your medication adherence…your diet…did you weigh yourself today? What was your blood pressure today? Those are extremely important. If you do not have a support person who is helping you do that, then I think that social robots could support that person who is living on their own and having a hard time with reminders and just adjusting to life as a heart failure patient…We all need a little push sometimes in the right direction and maybe social robots could provide that push.
(4) Limited responsibility for direct patient care	I like them as the mediator almost. Like they are the connector. They are not the service provider. I do not want them to be the service provider. I want them to be the connector.
	They do not have the ability to do a proper human assessment…They might not necessarily catch something that you would catch as an actual healthcare provider. I think that would be my biggest concern is missing something that you would have caught in person.
(5) Informed by patient/healthcare provider-centred design	It would be important to make sure that [the developers] are integrating and communicating with the clinicians to understand the conditions and what information a clinician would need that would impact care and improve the quality of care…I think they need to communicate with the clinicians to say here's the potential of our technology. What are the questions that are pressing in your field that would impact and improve quality of care?
	I think the most important thing is going to be patient acceptability and patient comfort. I think the challenge is going to be to ensure that those who design and develop and implement these are not 37-year-old IT whizz mans or if they are that they understand, or at least have some sense of the nature and circumstances, the needs and the challenges faced by senior citizens with chronic health problems…it is fundamental and essential that understanding of the environment and circumstances of those who are used going to use these devices is ingrained from the get go.
(6) Grounded in existing practice	Any radical new technology has to be grounded in existing practice. If it completely changed the way something is done, then it's not going to be adopted by people because it's just so different from what they do. It has to be grounded in the existing political process, but just do things more efficiently. I think you need to get buy-in because it's such a new thing.
	I think it's important for the engineers to see how a nurse looks after a heart failure patient in the hospital. How does a physician care for them in an office? I think they need to look at those elements of human care that are done. Then, we can parse out which aspects of it are needed, essential, and which aspects of that are inefficient or non-essential… set like a requisite criterion of what the minimum requirements are. And then be able to operationalize those, in these social robots, after understanding the context in which they are used and then just do them more efficiently.

Continued

Table 1 Continued

Theme	Example participant quotations
(7) Capable of supporting precision medicine goals and tailoring to patients' needs	You cannot make one mold and kind of lump everyone into it because even all our heart failure patients are different. Different needs and wants…the AI in it would have to be so good that it knew which question to ask to what patient. I think, for a developer, the personalization piece is important, and the ability to understand that patients are not all going to respond in the same way to a support resource and to have the ability to somehow modify that algorithm to enable personalization.
(8) Dedicated, hospital-integrated data management system with requisite staffing, support, and security	The robot is just a vehicle for transmitting information to someone who can do something, so you need that infrastructure to make it successful…but clinicians are too busy to read through rounds of data collection from a robot that's coming from a patient every day. That's not efficient for the system and it wouldn't work…I do not want all that data come to me… I already have a busy practice, so I would think that that data needs to be collected and managed, but by somebody other than me…Just imagine the volume, especially when we're talking about a hundred data points, if not more per day, per patient, that is coming to me… I would want nothing to do with that. I would say there needs to potentially be a separate team that is a remote or robot team, a robot medical team, where I only get involved when a cardiac-specific issue comes up and it's urgent or emergent enough that I need to be involved. I do not want to be teaching the patients that you have not got your audio hooked up or whatever. There's got to be a dedication of IT to be able to make this happen…You have to have the resources provided by the institution.
(9) Sustained parallel resources to support systemic issues that social robots may only partially address	I worry that this kind of technology is a band-aid solution for a different type of problem that is present in society. We have elderly patients that are alone and unsupported, and our society's solution is 'let's build a robot to keep them company and watch them?' That's kind of sad…How come our healthcare system is inundated, to the point that we cannot cope, that we need to create a robot to do what a human being probably could do better if we actually had the manpower to do it. Is it a fix or partial fix or band aid? It's almost like we are giving up on human beings…that's how I see it. We have got robots because we are giving up on human beings being able to provide that care…We need to increase capacity in our healthcare system rather than coming up with band aid solutions…We need to be having more people-based solutions…trying to better the infrastructure of the healthcare system, rather than trying to find solutions in a robot.

providing education or prompts to patients with heart failure, but there was a hesitancy to adopt the social robots in an interventional capacity. Healthcare providers representing diverse clinical roles were however, more accepting of integrating these technologies if several factors were addressed prior to implementation, including the development of efficacy and effectiveness data from well-designed experimental research and thoughtful strategies for streamlined health-systems integration.

In this study, healthcare providers' perceptions are consistent with a systematic review[21] ($n = 97$ studies involving >13 000 participants) that measured acceptance towards social robots in various applications (i.e. robots providing companionship, education, geriatric and paediatric care, and general human–robot interaction), either prior to or immediately following exposure to a social robot. In the review, acceptance varied substantially, but overall, 58% of studies suggested that individuals were accepting of social robots. This current study, along with the results from this systematic review, reiterate that the acceptance of social robots is currently mixed and is likely dependent on technology expectations (e.g. performance, usefulness, ease of use), users' profiles (e.g. demographic, psychological, and health information), the function and appearance of the robot (e.g. conducting simple to more complex tasks; humanoid and non-humanoid), length and type of exposure to social robots (e.g. physical encounter, video observation), as well as ambient social and environmental factors (e.g. social support, socioeconomic status, urbanicity, and culture).[22] As acceptability is consistently correlated with technology uptake,[23] measuring acceptability levels, and identifying factors associated with high and low levels of acceptability is warranted to target interventions and address modifiable barriers that inhibit users' willingness to engage with the technology. Due to the wide variability and several factors associated with acceptability across groups, it is advisable that health technology leaders and innovators ascertain perceptions from specifically targeted groups, such as those with specialities or sub-specialities in cardiology, as was considered in this current study. Extrapolating results from healthy populations, for example, may overlook important nuances integral to successful social robot interactions and system implementation for patients in advanced stages of chronic disease, including heart failure. To date, one small study[14] [$n = 28$ patients; 15 providers (nursing, physiatry, occupational, and physical therapy)] assessed attitudes following interaction with social robots for 18 weeks to enhance onsite cardiac rehabilitation exercise; 75% of patients and 80% of providers reported a positive perception after directly interacting with the social robot. Another study from the same research group ($n = 17$; all participants were patients attending cardiac rehabilitation), determined that participants enjoyed a social robot with personalization features (i.e. recognizing users, addressing users with their name, and providing tailored feedback) and felt that this robot was useful for improving engagement at the session and providing motivation to attend. Standard guidelines for the intervention were not reported, and it is unclear whether any patients had been diagnosed with heart failure or how patients and/or providers might react to a robot being used in a patient's home. Contemporary investigations are needed as the COVID-19 pandemic has rapidly increased the uptake of virtual care tools; indeed, interest in social robots has since expanded, particularly among older populations, those who are socially isolated and lonely,[24] and among healthcare professionals.[25]

According to recent prognostics, the social robot market is expected to reach a market size of $912 million in 2026, a 43% increase from 2019; the North American healthcare sector is projected to experience the fastest market growth. Our qualitative data suggest that providers expect high-quality evidence to support the use of social robots in the care of patients with heart failure. High-quality experimental research is currently lacking and will be required to support healthcare leaders' decision-making in virtual care services. Currently, virtual health tools do not require clinical effectiveness data prior to marketing as a disease prevention and management product.[26] Often, we simply do not know if these technologies are helpful, harmful, or inconsequential. Recent systematic reviews have indicated that while promising, the outcomes of mHealth interventions have not yet been demonstrated at scale.[27] In virtual care trials, specifically, results are seldom compared to in-person patient–clinician interactions, have largely been restricted to examinations of non-embodied virtual agents and implantable and non-invasive/wearable technologies, and the methodological quality of experimental studies is highly variable.

The potential educational value of social robots was articulated by the participants in the study, particularly as a tool to remind patients of their appointments and to improve medication adherence, as well as to provide prompts for the uptake and continuation of health behaviours to mitigate risk (e.g. engaging in physical activity, social interaction). The providers in this study desired advanced capabilities in data collection, collation, and transmission, but some capabilities extended beyond their comfort level in delegating to social robots (e.g. conducting a physical assessment). They were also concerned about assigning responsibility for direct patient care. Furthermore, the safety, equitability, and patient-centredness of such technologies in supplementing or supplanting traditional care remain in question.[28] To further enhance the robustness of social robot trials, future interventions may need to address the considerations highlighted by participants in this study. This would involve directly engaging patients and providers to inform the social robot design, barriers to use, and to identify the most relevant clinical outcomes. Embedded and grounded in existing practice, artificial intelligence would need to be adaptable to align with precision medicine models of care. The success of social robot interventions may ultimately hinge on effective health-system integration, which would require substantial coordination between technology experts, healthcare leaders, and patients and providers alike.[19] The providers surveyed identified that this would require substantial support from information technology and human resources; without this, respondents were fearful that the burden may fall on them, adding to their responsibilities for their provision of care rather than extending their ability to provide care. Social determinants of health, including downstream markers such as loneliness and social isolation, and upstream markers such as healthcare access and equity of services, remain significant healthcare issues, unlikely to be remediated by the usage of social robots, but these factors need to be included in developed trials. It remains unclear whether the rerouting of resources to social robots would result in significant individual and societal benefits over and above traditional care in cardiovascular medicine. High-quality studies are now required to substantiate such an investment, both economically and ethically.

Limitations and conclusion

Although the sample size is not considered a limitation, as it is appropriate for qualitative research, larger, observational studies are still needed to determine the generalizability of the key considerations that were identified. The quota-based purposive sampling utilized in this study enhances the potential representativeness of the data to other large cardiovascular care centres in countries that are more technologically advanced. However, the sample of healthcare providers was predominantly white, female, and largely comprised of medical doctors with specialities in cardiology or cardiac rehabilitation. The perspectives of other healthcare providers who also interact with patients with heart failure (e.g. pharmacy, occupational therapy, palliative care, emergency, and ambulatory care), including those in community-based healthcare centres, were not included in this research but would be worthy of investigation in future research. Consulting those with expertise in hospital-based information technology services, and those responsible for virtual care regulatory policies and procedures would also enhance the scientific literature. It will also be important to investigate the perspectives of healthcare providers within privatized healthcare systems as this research was conducted in a country with a decentralized, universal, publicly funded health system. In addition, the selection of videos that participants viewed prior to completing the interview may have influenced their interpretations, but this introduction was deemed necessary as several providers were unfamiliar with social robots prior to participating. As this was early-phase research and we were conscious to not restrict participants' perspectives of social robots to a particular prototype, we opted to not provide a demonstration of a physical robot prior to the data collection. However, it is possible that providers' perspectives would have been more favourable to the use of social robots in direct clinical care if they had the opportunity to interact directly with a robot, as has been indicated elsewhere.[18] In addition, it is possible that interacting directly with a social robot would allow participants to envisage the unique *social* opportunities of social robots beyond the more physical or informational functionalities. Lastly, the present study was designed to obtain perspectives from healthcare professionals who provide care to patients with heart failure. It did not involve patient or family caregiver perspectives. Obtaining patient and caregiver input is our next step in informing a social robot intervention for this population. As per behavioural clinical trial development guidelines, the results from this research will inform the study protocol (i.e. interview guide and quantitative instruments) for a subsequent early-phased study involving patients and family caregivers.

In conclusion, the results provide several points for consideration in the implementation of social robots for heart failure patient care, informed by the healthcare providers' perspectives. These perspectives are required to improve understandings of desired social robot capabilities, optimize social robot efficiencies, increase their uptake among patients and providers, while protecting patients' and providers' best interests, particularly as social robot technology becomes more widely utilized in the healthcare system.

Supplementary material

Supplementary material is available at *European Heart Journal – Digital Health*.

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Conflict of interest: None declared.

Data availability

The dataset is not publicly available due to the sensitivity of the data (i.e. transcribed interviews from healthcare providers from one hospital site) and is available from the corresponding author upon reasonable request.

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