REVIEW ARTICLE

AI and Human-Robot Interaction in Healthcare: A Narrative Review

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ABSTRACT

Artificial Intelligence (AI) and Human-Robot Interaction (HRI) is multidisciplinary field that explores the dynamic interaction between human with human-like across social, cognitive, ethical, and technical dimensions. This review synthesises benefits and challenges faced in AI-HRI in the field of healthcare, categorising the literature into various thematic areas like social interaction and emotional engagement in children, mitigating social isolation in elderly, ethical considerations, reducing burden on healthcare workers, rehabilitative robots, surgical robots and eventually increasing the efficiency of workflow in hospitals. Foundational works establish the significance of autonomy, collaboration, and multimodality. At the same time, recent studies emphasised the significance of empathy, user acceptance, and the subtle impact the robots can have in social and domestic settings. Ethical analysis highlights both potential risks and benefits of AI-HRI, particularly in special group of population like specially-abled children, elderly, etc. Application-based research further highlights the importance of robots in service-related to healthcare, and hospitality environments. Affective computing helps create systems that understand emotions, making interactions with technology feel more natural and human-like. Together, these insights chart a comprehensive landscape of HRI, informing the benefits and risks of socially and ethically responsible robotic agents.

KEYWORDS

Artificial Intelligence; Ethics; Health Care Delivery; Human-Robot Interaction

INTRODUCTION

Over time, robotics has experienced substantial advancement, with the most notable progress seen in industrial applications. In contrast, the healthcare sector has received comparatively less focus, likely because of the inherent challenges involved in delivering interpersonal care, which is central to healthcare services (1). While there was an initial slow development of robots in patient care, the situation has definitely shifted following the COVID-19 pandemic, which hastened the adoption of robots in service delivery safely in developed as well as developing countries around the globe (2).

Earlier robotics has largely been motivated by the goal of automating tasks, in other words, making life simpler and easier. Clearly research shows that people experiencing interactions with other people, pets and even robots, as more enjoyable and motivating than interacting with screen.(3)Robotics is now assisting people by not only performing manual tasks, but also by promoting social connections and motivating individuals to improve the quality of their work. As these technologies continue to advance, studying how people and robots interact has become a key topic for researchers in diverse fields of healthcare, engineering (production), and domestic environments (4). Following the COVID-19

pandemic, robotics is now more commonly utilised for facilitating social interaction, particularly within healthcare services, rather than for traditional industrial applications. Owing to its ability to improve accuracy and operational effectiveness, assistive technology is becoming an increasingly important component within the healthcare sector (5). Khan et al. classified the applications of robots in healthcare into multiple distinct roles, such as receptionist, nursing, ambulance services, telemedicine, service delivery, cleaning, disinfection, surgery, radiology, rehabilitation, food delivery, and outdoor logistics (1). Another aspect is very well known as Artificial Intelligence (AI) is a field of computer science where machines (like computers or robots) are designed to mimic the way humans think, learn, and solve problems. AI involves the simulation of biological intelligence in machines (6). Such rapid expansion of data and the enhanced computational capabilities to store, process, and analyze it have been key drivers of AI advancements, leading to its wider adoption everywhere, including medicine.

Human-robot interaction (HRI) involves designing, evaluating, and implementing systems that facilitate meaningful exchanges between humans and robots, fostering collaboration and enhancing user experience (5). HRI growth has been substantial as robots have become incorporated into daily life, influencing diverse environments including residences, public areas, and workplaces. The presence of assistive robots, particularly for the elderly, highlights their potential to provide support and enhance quality of life. Su et al. (2023) provided a systematic review of multimodal HRI, including voice, image, and bio-signal inputs like EEG, indicating naturalistic communication (7). The growing reliance on these technologies emphasises the need for a comprehensive understanding and research into HRI, focusing on the nuances of user experience and social engagement. Hence, this research intends to focus on the advantages and difficulties linked to this integration, fostering positive relationships between humans and emerging robotic systems. Like robotics into societal frameworks necessitates a thorough understanding of human-robot relationships to ensure safety and usability (8). As these technologies become more pervasive, dynamics such as trust, collaboration, and acceptance between humans and robots play critical roles. Addressing these factors would require focus on participatory governance that engages all stakeholders, ensuring that their concerns would develop clear ethical guidelines on robotic and frameworks for interaction can help in mitigating potential risks to patient safety and enhancing their acceptance.

This review aims to integrate recent research on HRI and AI within healthcare focussing on major themes, existing obstacles, and prospective developments in the field.

MATERIAL & METHODS

This article presents a narrative review aimed at synthesising recent advancements and key thematic developments on advantages and obstacles faced in the field of AI and HRI in healthcare. It focuses on key thematic areas of benefits and risks in healthcare which are: social interaction and emotional engagement, loneliness mitigation in elderly, enhancing disease precision and accuracy, support for healthcare workers, increased efficiency in hospital workflow, remote area service provision and rehabilitative robots. Ethical consideration in HRI in healthcare is a huge challenge. Relevant literature was identified through a comprehensive search strategy in 'PubMed' and 'Google Scholar' databases, covering recent publications from past two decades 2004-2024, making certain that the assessment was based on the most relevant and latest research in the discipline. Using following combinations of keywords "HRI", "human-robot interaction", "AI", "social robots", "Artificial Intelligence" and "healthcare" the search was conducted and found 137 articles. After the 'Title' screening process 86 articles were selected and after 'Abstract' screening procedure 45 articles were selected. The empirical studies, systematic reviews, meta-analyses and reviews were selected according to established inclusion and exclusion criteria developed specifically for research in human-robot interaction and artificial intelligence in healthcare domain. The inclusion criteria specified that chosen sources must be in English and focus on recent advancements in AI and in robotics in healthcare, while non-academic sources, studies on AI or HRI not related to healthcare in any way and non-English articles were excluded. A qualitative and thematic approach was used to synthesize findings. Selected studies were grouped based on emerging themes under broad headings of 'Benefits' and 'Challenges'.

Benefits:

Social Interaction and Emotional Engagement

In this busy world, due to a lack of enough parenting time, research suggests that engaging social robots can influence children's emotional development, although the effects vary based on robot design and interaction context. Studies have shown that robots can improve social skills, like identifying emotions

in children diagnosed with Autism Spectrum Disorders, leading to significant improvements in performance during interactions. Moreover, robots that employ emotional gestures during interactions have been found to reduce anxiety and enhance trust, facilitating better emotional experiences for children during stressful situations. Overall, the design and behavioural responsiveness of robots play crucial roles in promoting emotional engagement and positive social outcomes in various settings (9,10). These studies collectively highlight the critical role of social behaviour, emotional intelligence, and expressive design in making robots not just tools, but companions capable of meaningful interaction.

Mitigating Social Isolation in Elderly

Elderly users are generally receptive to robotic assistance, especially when systems are designed with empathy, simplicity, and emotional expressiveness. Studies show that emotionally engaging robots like pet toys and personality-driven models enhance user satisfaction and acceptance. Prioritizing emotional and social support in assistive technologies is key to improving quality of life and fostering adoption among ageing populations (11,12,13). The adoption of robots in elderly care is rapidly becoming an essential approach to address the rising need for home-based healthcare services as the population ages (14). Advanced systems like the RobWell initiative utilise AI to monitor mood and support daily activities, ultimately aiming to enhance the mental well-being of elderly individuals (15). Studies like Cantone et al. demonstrate that companion robots can provide social interaction and monitor health status, helping to mitigate isolation and offer timely care through real-time updates to caregivers and medical personnel (15,16).

Di Nuovo et al found that elderly users, particularly those with limited experience using technology, responded positively to the usability of robotic services and were open to adopting them, recognizing their potential benefits (12). Additionally, the design and functionality of these robots are being developed with user preferences in mind, facilitating the needs of elderly users and addressing loneliness effectively. Smarr et al. (2014) show that elderly individuals are receptive to robotic assistance in specific tasks, like household chores or companionship, which can reduce their loneliness and improve quality of life. However, it was seen that they prefer human help for personal and recreational activities (17). Villarreal-Zegarra et al. (2024) performed a meta-analysis and found that while animal-assisted and digital-assisted therapies reduce depression, pet-robot interventions had a limited impact, signalling a gap in emotional effectiveness (18).

Overall, a focus on empathetic design and user-friendly interfaces can significantly influence elderly users' willingness to embrace robotic assistance. While robots show potential in eldercare, emotional depth and contextual awareness are key. Robotic companionship must evolve beyond functionality to achieve the benefits seen with biological or digital therapy systems. However, the ethical implications of deploying these robots raise questions about human dependence versus liberation, calling for a balanced approach that respects the dignity and privacy of elderly individuals (19).

C. Enhancing Disease Precision and Accuracy

The rapid growth of data and improved computational power to store, process, and analyze are major factors driving AI progress. This has led to its broader use in medicine, especially in areas like disease risk prediction, evaluation of any type of skin lesion, detecting cancer cells and precision medicine and many more (20,21). Independent research efforts in both AI and healthcare have led to the creation of sophisticated algorithms that are changing how medicine is practiced (22).

For instance, the incorporation of AI into surgical procedures represents a major advancement, offering greater precision, efficiency, and speed. Robotic-assisted surgeries powered by AI have shown significant promise in enhancing outcomes, minimizing human errors while enabling complicated operations. In 2018, the FDA authorized an AI-based system for diabetic retinopathy screening, highlighting how AI is being recognized and integrated into healthcare services (23). While complexity and variability of surgical environments initially posed challenges for AI adoption in surgery, its applications have expanded significantly. AI now plays a vital role in Robotic-Assisted surgeries (24), surgical decision making (25), image-guided procedures, navigating endoscopy (26), pre-operative risk prediction, and intraoperative video-analysis (27). Additionally, AI is used in surgical education by creating 3D simulations and virtual reality tools that help train surgeons. These AI-powered labs provide skill-focused practice, making surgeons more confident and helping lower the risk of complications (28). AI has enhanced surgical performance in robotic-assisted and minimally invasive surgeries. Many clinical trials and case studies have demonstrated its effectiveness for use in imaging during surgery, especially in the operating room, differentiating healthy and cancerous tissue and accurately resecting it (29).

D. Support for healthcare workers

During the prolonged fight against COVID-19, social isolation and loneliness have emerged as significant challenges. Innovative technologies, such as social robots, have been proposed to facilitate remote human interaction, helping to alleviate loneliness by mitigating the human contact risk while easing the burden on health facilities (30).

Japan, with the highest proportion of elderly (75+) among OECD nations, faces growing strain on its healthcare system. Nurse robots are increasingly used in hospitals to ease the burden, as staffing shortages and high caregiver stress persist. Many citizens also leave their jobs to care for aging relatives, prompting the government to adopt technological solutions for elderly care (31). Some research suggests that mobile robots may improve older adults' quality of life and help make caregivers' jobs easier.

E. Increased Efficiency in Hospital Workflow

IBM introduced 'Watson' for Oncology in 2013, marking it as the first medical diagnostic robot. Utilizing AI to process large volumes of medical information, it supports doctors make critical patient care decisions, saving a lot of time. During pandemics like COVID-19, such diagnostic robots have proven especially valuable by reducing direct physical contact between patients and physicians, keeping them disease-free, less absenteeism at work, increasing productivity, efficiency in their work, which ultimately enhances efficiency in hospital workflow (32).

F. Enhanced Access to Healthcare in Remote Areas

In hilly areas, forest areas, and any difficult-to-reach areas, AI-driven robotic assistance in the form of telemedicine or drones has been of great help. Telemedicine is an effective and practical solution for individuals in remote or rural areas, offering improved access to healthcare services. Beyond patient care, it also serves as a learning platform for students and medical professionals. It made connection easier for healthcare professionals in remote areas to patients by overcoming location-related challenges (33). Additionally, Jennett PA et al. emphasize notable socio-economic advantages for patients, families, healthcare professionals, and the overall health system, such as enhanced communication between patients and providers and expanded educational opportunities (34).

Reddy et al. (2019) reported that AI chatbots were utilized for triaging patient queries, scheduling appointments, and conducting initial assessments, thereby improving overall efficiency (35).

G. Robots for Rehabilitation:

Rehabilitation involves helping a patient regain the ability to return to everyday life and routine activities. Providing patients with ongoing, progressive exercises is particularly beneficial for individuals with physical impairments. Rehabilitation robots, equipped with sensors and actuators, support neurorehabilitation by enabling precise movement control and monitoring. Devices such as exoskeletons and powered limbs assist the elderly, injured, disabled, and even healthy individuals through guided or passive movement support. Upper limb rehabilitation devices are designed for individuals experiencing mobility limitations due to conditions such as stroke or hemiplegia. Lower limb rehabilitation primarily focuses on using exoskeletons to help patients relearn walking patterns. A key example is the Lokomat, a robotic bilateral orthosis that provides full-body weight support and facilitates gait training (36).

Challenges

A. Workforce challenge

Artificial Intelligence (AI) in healthcare, especially in surgery, is becoming increasingly important, especially through robot-assisted operations and AI-powered surgical robots. Biomedical companies have heavily invested in this area over the past two decades. However, there are rising concerns about AI leading to replacing healthcare workers and causing skill loss (37).

B. Overdependence on AI-powered Robots

Clinicians are becoming more reliant on technology, leading to a gradual loss of hands-on and interpersonal skills (24,38). In surgery, overdependence on AI may reduce core knowledge and practical ability. If the system fails, surgeons without traditional training may struggle, putting patients at risk. Regular practice of conventional methods is crucial for an effective response. Overemphasis on AI in training may cause skill loss and reduced confidence, especially when AI decisions conflict with clinical judgment (39).

C. Loss of Skills

Deskilling in healthcare is another leading concern, ultimately affecting patient safety. Studies show that doctors getting fewer opportunities for hands-on patient exams, observing symptoms, interacting with patients, and making clinical decisions. As more time is spent on apps for patient data and less on direct interaction, leading to worsening of communication skills as history taking still remains a crucial diagnostic tool and technology should support, not replace it. Diagnostic reasoning relies on quick recognition of patterns gained through human interaction (40).

D. Hampering Decision-making

Reliance on AI in surgical procedures, especially by new surgeons, may reduce their skills or proficiency in decision-making, leading to greater dependence on algorithms over clinical judgment (41). While AI

improves diagnosis, treatment, and surgical planning, it might lessen the surgeon's ability to make independent clinical judgments. Its data-driven recommendations are valuable but may result in less autonomy for the clinician (42).

E. Patient Safety Compromised

Surgeons may overly trust AI, weakening critical thinking and risking patient safety in complex cases. Balancing AI with clinical judgment is essential to maintain surgical integrity and patient trust (43). Because these systems rely on data and algorithms, their results are shaped by the data used during training, which can introduce different types of bias. Akingbola et al. reviewed this issue and described three main kinds of bias present in AI applications for cancer care (29,40).

F. Lack of Training

While many physicians lack sufficient knowledge and hands-on experience to use an AI-driven robot effectively (44). Insufficient knowledge of AI can negatively impact performance and efficiency. Patients usually do not fully understand how AI was used in their treatment, so when they want more clarity, they tend to consult a doctor(45).

G. Rising Ethical Concerns on Human-Robot Relationship

Research done by de Graaf (2016) evaluates the ethical implications of forming relationships with robots, raising questions about autonomy, dependency, and authenticity (46). Prescott & Robillard (2021) expand on this by comparing human-robot relationships with those humans have with animals and other humans, emphasising the need for a balanced view of potential psychological risks and benefits of human-robot relationships, particularly regarding emotional fulfilment and social isolation (47). The exploration of ethics in human-robot relationships considers how these interactions impact social dynamics and emotional well-being (48). Care ethics emphasises the importance of interpersonal relationships, advocating for a framework that values the emotional and bodily aspects of these interactions, particularly in workplace settings with robots (49). Rapid growth of AI-driven robots and software in medicine has raised major ethical concerns, especially about accountability for negative outcomes (50). Even though decisions involve input from the surgeon, the institution committee, and AI systems, it is usually the surgeon who carries the responsibility for the final choice (51).

Ethical concerns affect both users and creators of robots who design, develop, and regulate robots. As robots become more advanced, they collect, store and analyse large amounts of sensitive data like eating or sleeping habits, raising serious privacy risks if misused or exposed. Hackers can misuse robots to cause harm or steal data, highlighting the need for strong, regularly updated security. Responsibility for robot-caused harm is complex, with no clear answer on whether the blame lies with the maker, coder, user, or the robot itself (52). Clinical training should be a priority for surgical trainees. Surgeons need strong skills in both AI-driven robots and traditional surgical techniques to stay competent (44). There is a need for ethical standards that clearly outline what is expected of surgeons and AI systems when making clinical decisions (53).

RESULTS AND DISCUSSION

1. Technical and Implementation Gaps: Predominance of case studies, short-term pilot studies with heterogeneous outcome measures; limited comparative effectiveness trials against standard clinical care; absence of long-term follow-up data on patient outcomes, trust trajectories, and dependency patterns; and underrepresentation of low- and middle-income healthcare settings where HRI deployment could have significant public health impact.

2. Ethical and Governance Gaps: Presence of fragmented regulatory frameworks, noting the absence of unified international standards for AI-driven HRI in clinical settings, addressing gaps in taking consents for vulnerable populations (children, elderly, cognitively impaired), transparency requirements for algorithmic decision-making, liability and accountability structures, and data governance frameworks specific to sensitive healthcare contexts.

3. Evidence Inconsistencies: We highlight conflicting findings regarding emotional attachment to robots (some studies show benefits in reducing isolation; others warn of unhealthy dependency), varying efficacy across different patient populations and care contexts, and insufficient evidence on the generalisability of findings.

4. Concrete Research Recommendations: Multiple-site randomised controlled trials embedded in routine clinical practice across diverse healthcare settings, longitudinal cohort studies examining sustainability of HRI benefits, user satisfaction, participatory design research involving patients, caregivers, clinicians, and engineers to co-create contextually appropriate HRI solutions, mixed-methods research combining quantitative outcome measures with qualitative exploration of trust, safety perceptions, and ethical concerns is needed.

5. Policy and Implementation Recommendations: Development of national AI and HRI governance frameworks, Mandatory transparency standards for AI-driven clinical decision support within

healthcare systems, Establishment of interdisciplinary oversight committees (including clinicians, ethicists, engineers, and patient representatives) for AI-HRI deployment decisions, Creation of clinical training and competency frameworks for healthcare professionals working with AI-HRI systems

CONCLUSION

AI-HRI has evolved from technical into an interdisciplinary field of healthcare primarily after pandemic. The intersection of empathy, social behaviour modelling focuses on designing robots that understand, respond, and adapt. These studies show that human expectations, trust, and emotional comfort are vital for the acceptance and success of AI-driven robots, especially in sensitive domains of healthcare like pediatric and geriatric care, education, and rehabilitation. Ethical dimensions explored reinforce that as robots grow increasingly social and autonomous, the lines between human-tool and human-partner blur. We must carefully consider how such relationships shape societal norms and individual well-being. However, gaps remain in scalability, ethical governance, and emotional authenticity.

Bringing it all together, the future of AI and HRI in healthcare lies in harmonising functional intelligence with genuine social intelligence, ensuring that robots augment rather than replace human care, and that they operate with unwavering ethical consideration and patient safety as foundational principles. Realising this vision demands inter-departmental and inter-disciplinary collaboration between clinicians, biomedical engineers, designers, ethicists, and psychologists working synergistically from the earliest stages of system design through implementation and post-deployment evaluation. Only through such integrated, ethically-grounded, evidence-informed approaches can make AI-driven and HRI enhance healthcare delivery while safeguarding human dignity, autonomy, and wellbeing.

AUTHORS CONTRIBUTION

Concept finalization, data compilation, data analysis and manuscript writing has been done by NJ and MT contributed to the conceptual framework of the study along with data interpretation. Literature review along with quality check has been aided KJ. Final data compilation along with quality check has been contributed by KJ.

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CONFLICT OF INTEREST

None

DECLARATION OF GENERATIVE AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

The authors haven't used any generative AI/AI assisted technologies in the writing process.

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