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Exploring the Role of Robotics in Nursing Care for Elderly Patients: A Comprehensive Review

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Abstract

Background: As the global population ages, the demand for innovative solutions in elder care is increasing. Robotics offers promising advancements in nursing care for elderly patients, addressing challenges such as mobility, social interaction, and health monitoring. This review explores the integration of robotic technologies in nursing practices, emphasizing their potential to enhance the quality of care for older adults.

Methods: A comprehensive literature review was conducted, analyzing peer-reviewed studies published between 2015 and 2023. Databases such as PubMed, IEEE Xplore, and Google Scholar were searched using keywords related to robotics, nursing care, and elderly patients. The review assessed various robotic applications, including assistive robots, telepresence robots, and robotic mobility aids, evaluating their impact on patient outcomes, caregiver efficiency, and overall healthcare delivery.

Results: The findings indicate that robotic technologies significantly improve the quality of care for elderly patients. Assistive robots enhance daily living activities, while telepresence robots facilitate remote consultations, reducing the need for in-person visits. Additionally, robotic mobility aids help prevent falls

and promote independence among seniors. The studies reported increased patient satisfaction and decreased caregiver burden, highlighting the positive reception of robotic interventions in nursing settings.

Conclusion: Robotics in nursing care presents a viable solution to meet the growing needs of elderly populations. The integration of robotic technologies can enhance patient autonomy, improve health outcomes, and alleviate pressure on healthcare systems. Future research should focus on long-term effects, ethical considerations, and the development of interdisciplinary training programs for healthcare professionals to optimize the use of robotics in elder care.

Keywords: Robotics, Nursing Care, Elderly Patients, Assistive Technologies, Telehealth.

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1. Introduction

Nurses form the foundation of the healthcare sector, and the nursing profession has traditionally represented the greatest portion of the healthcare workforce. Increasing healthcare expenditures and an aging population are both concerns affecting healthcare systems and the nursing profession (1). Population aging is becoming a worldwide phenomenon with significant financial and social ramifications. In the European Union, the population of individuals aged 65 and over is anticipated to increase from 101 million in 2018 to 149 million by 2050. In terms of percentage, there will be a rise of 17.6% and 60.5% of individuals aged 65–74 and 75–84, respectively, in the EU-28, while the most significant growth is anticipated for the elderly population (≥85) at a rate of 130.3%. Conversely, those aged under 55 years will decrease by 9.6% throughout this timeframe (2-4).

The old age dependency ratio (OADR) is anticipated to increase from 30.5% in 2018 to 49.9% in 2050, indicating a decline from around three working-age individuals (ages 15 to 64) per older adult in 2018 to two individuals by 2050, while the worldwide OADR is forecast to attain 28%. Elderly individuals face numerous challenges on a personal level, encompassing social (neglect, isolation, fear, loneliness, boredom), financial (limited income, anxiety about being a burden, insufficient insurance), psychological (depression, memory impairment, dementia, insomnia), and physiological (diminished cognitive function, reduced reflex efficiency, muscular weakness, impaired balance, falls, and fragile bones) (3). Consequently, elderly individuals require specialized care that friends and family sometimes cannot provide, resulting in a prevalent trend towards institutionalization.

To address the current deficit of nursing and caring personnel, along with escalating healthcare expenses, the use of diverse technology solutions has been suggested. Technologies that have developed to facilitate independent living and aging-in-place principles include "Ambient Assisted Living" (4). The objective of these technologies, often known as "smart home" technologies, is to facilitate independent living by the strategic installation of sensors inside a residential environment (either fixed or wearable). The sensors include magnetic switches, temperature sensors, photosensors, water flow sensors, motion sensors, force sensors, smoke detectors, and biosensors for vital signs. Ambient monitoring systems may record daily activities, which can be used in two specific manners: to detect short-term crises and to assess long-term health status modifications (5,6). Although these technologies are pertinent to patient and senior care, additional examination is beyond the purview of this study, which concentrates on robotics-related technologies.

From a robotics standpoint, properly engineered systems may alleviate the workload of nursing personnel in hospitals and nursing homes, while also performing general helpful functions at home, without diminishing the quality of care and enhancing the quality of life. The aforementioned functions highlight the contrast between nursing robots and assistive robots:

a. Nursing robots may function as auxiliary healthcare personnel in hospitals, eldercare institutions, and domestic settings. They may execute logistical and labor-intensive physical chores, alleviate loneliness and idleness among the elderly, or do regular assignments such as monitoring patients' vital signs. Remote-

controlled telerobots may perform interactive caregiving tasks and function as conduits for physicians and/or nurses to engage with patients and/or the elderly from a distance.

b. Assistive robots may assist handicapped and elderly individuals in leading healthy, autonomous, and productive lives. Assistive robots are categorized based on their principal function into two groups: "Socially-assistive" and "Physically-assistive." The former aids users via social engagement, while the latter provides support through physical interaction.

Advanced functionalities for the aforementioned robotics technologies are present within the broader context of telerobotics and telemedicine. Nursing and assistive robots are components of the broader domain of healthcare robotics, which also include medical robotic systems. The latter has been a focus of much study, and several systems have already been used in clinical practice. Robotic systems are now used in surgical specialties, including general surgery, orthopedics, and neurosurgery, as well as in other therapeutic interventions, such as radiation therapy. The use of nursing and assistive robots presents several problems, including technical, clinical, financial, insurance, psychological, social, ethical, and legal issues. Technological problems include indoor navigation, manipulation, safety, telecommunications, and the integration of robots with current in-hospital systems. Prominent integration instances include the linkage to hospitals' enterprise resource planning (ERP) and electronic health records (EHR) software systems. Nursing robots are tasked with executing logistical activities and measuring vital signs, respectively. User views and attitudes about nursing and assistive robots are anticipated to have a crucial role in the future and influence of these technologies. This is pertinent from the perspectives of patients, the elderly, nursing personnel, and caregivers (8).

This paper aims to provide an overview of the burgeoning domains of nursing and assistive robotics to underscore their promise and delineate the associated obstacles. The latter offers directives for robotic design and guidance for future advancements in these domains. Informed design may provide robotic systems that are more functional and efficient, enhancing their ability to fulfill their intended purpose. The document is structured as shown below. The document begins with an overview of nursing robots in the part titled Nursing Robots, followed by a discussion on socially-assistive and physically-assistive robots in the sections Socially-Assistive Robots and Physically-Assistive Robots, respectively.

2. Robots in Nursing

Nursing robots have a function in both hospitals and eldercare settings. Robots may efficiently alleviate the workload of nurses, enabling them to focus on responsibilities related to their core functions. Robotic robots have been deemed effective in facilitating the delivery of meal trays, medications, and laboratory specimens inside a medical setting. Robots may also automate logistical functions pertaining to the storage of medical equipment and supplies. In addition to these responsibilities, an advanced role for robots involves cooperating with nurses to augment their efforts and improve efficiency. Furthermore, robotic nurses may minimize the work exposure of human nurses to harmful illnesses or chemicals. After specialized training, nurses may have the responsibility of coordinating and supervising the operations of a robotic fleet inside a hospital, so establishing a new professional specialty.

Custom-engineered robotic devices that assist with patient transfers, ambulation, and lifting may substantially alleviate physical strain on nurses. Caregivers often experience back discomfort and occupational ailments. Custom-designed robotic equipment may be allocated arduous jobs, such as transporting and relocating patients (9). This facet also pertains to the broader investigation of wearable exoskeleton technologies. Exoskeletons may augment an individual's physical ability, enabling the lifting of greater weights (power extenders) and mitigating musculoskeletal problems. Exoskeletons serve as an alternative to completely automated robotic systems, hence maintaining human capabilities in the workforce.

Nursing robots may further provide services for telemedicine applications (10). Robotic nurses equipped with telepresence systems may efficiently function as intermediaries for physicians to interact with patients remotely. Common situations include standard virtual consultations in which the robot traverses hospital wards, using the onboard display to achieve necessary visual interaction with the patients being

assessed. In this regard, equipping robots with autonomous navigation skills is a notably appealing attribute, alleviating the need for humans to manually guide robots to identify a specific patient. Furthermore, the robot may take the patient's vital signs at specified intervals as necessary for diagnosis and standard clinical procedures. This scenario extends to the patient's home, providing specialized treatment to individuals and healthcare facilities in distant and isolated regions.

Electromechanical caretakers provide distinct benefits over human caregivers, notably their ability to operate constantly throughout the day. As programmable devices, robots possess the capability to customize care and adapt to diverse requirements. Robots may be connected with hospital technology, including cloud-based EHR systems, enabling access to a patient's whole medical history and assuring continuity of treatment.

3. Socially Assistive Robots

A socially-assistive robot is a kind of assistive robot that aids end-users via social contact. The inherent human inclination to ascribe human traits and intents to mobile physical beings makes robots more effective than any computer software or smartphone mHealth application. The literature discusses potential applications of socially-assistive robots, including: (i) companion robots; (ii) assistance for persons with dementia; (iii) encouragement of physical activity; and (iv) facilitation of post-stroke rehabilitation (11).

Companion robots have developed into a distinct classification within assistive robotics. A key function has been to serve as interfaces for the elderly, enhancing their social life while facilitating connections with family and friends (12). Socially-assistive robots has the capability to monitor elderly patients via video surveillance and to notify caregivers of patient activities. Additionally, robots may provide elderly individuals news and entertainment, reminders for medication compliance, and support for physical activity. Conversely, robotic pets have garnered significant interest as a means to alleviate stress and sadness, while circumventing the challenges and hazards associated with animal care (11). A significant focus of socially-assistive robots is aiding those afflicted with dementia (13–16).

Regular physical exercise is crucial for senior adults to sustain and enhance health, promote mental and physical well-being, and reduce the risk of melancholy. Robots have been engineered to include older individuals in physical activity, guiding training sessions, while assessing user performance and delivering real-time feedback. Görer et al. (18) recognized two possible obstacles in the deployment of these robots. Firstly, the automated interpretation of the coach's motions must be accurately replicated; secondly, the robot's distinct physical embodiment differs from that of the coach. The use of robotics also encompasses post-stroke exercise and rehabilitation, which often includes meticulously structured repetitive, passive, or active activities (11). A movement therapy robot may provide either diagnostic (measurement and evaluation) or therapeutic (functional enhancement) advantages.

4. Robots for Physical Assistance

Two fundamental components of independent living that directly correlate with the quality of life for both the elderly and ill are: (a) the maintenance of movement; (b) the capacity to use items. In senior populations, several medical disorders, including strokes, neurological illnesses, bone fractures, and diminished muscle strength, result in the loss of mobility. Robotic methods have been developed to aid in standing, sitting, and walking in response to this circumstance (19,20). Robotic wheelchairs provide users independence, improved mobility, and safety (21). An adequate mechanical framework for the robotic wheelchair may surmount architectural constraints, such as rising and descending curbs (22). A robotic wheelchair may hierarchically integrate: (i) low-level functions (e.g., obstacle avoidance, corridor alignment) and (ii) high-level functions (e.g., navigation direction).

Well-designed assistive robotic manipulation systems may aid individuals with motor impairments, including restricted hand and arm motions, severe spinal injuries, or tremors. Surveys have delineated the specific requirements of disabled individuals in this cohort concerning assistive devices for various activities: eating and drinking (feeding assistive devices); personal care (washing, shaving, applying

cosmetics); object manipulation (books, devices); mobility and access (opening doors); and general reaching and movement tasks. Manipulation devices designed to tackle the above described issues might be either stationary or mounted on wheelchairs (23,24).

5. The Function of Telerobotics

In the broader realm of healthcare, teleoperated medical robotic systems have been effectively used, enabling operations, treatments, and diagnosis to be performed remotely over wired and/or wireless communication networks (25). Recent advancements in telerobotics and related supporting technologies, such as robotic manipulation and video streaming, enhance the efficacy of nursing and assistive robots while expanding their areas of use. Robotics gear elevates telepresence to a more natural and efficient standard by enabling movement and the execution of manipulation activities in distant settings. Telerobotics technologies relevant to nursing may enhance the situation of virtual doctor appointments. The user may remotely operate the robot using an inbuilt adjustable camera to find a patient in the clinic or specify a series of destination locations for autonomous navigation. Bidirectional video conferencing enables the physician to appear on the robot's display and interact with the patient to evaluate their present clinical condition (telehealth). Real-time medical charts can augment and improve remote clinical assessments through a robot-mounted device that possesses vital signs acquisition capabilities and EHR connectivity (26).

Telepresence robots assisting elderly people at home may enhance social contact, promote social engagement, and enable family to conduct virtual visits, fostering a sense of closeness. They provide communication with physicians and nurses to remotely oversee health and deliver necessary assistance. In contrast to video conferences, a telepresence robot elevates engagement to a more organic level due to the system's mobility. Improved functionalities for telerobotic systems may be achieved due to their intrinsic compatibility with IT technologies, such as the internet of things (IoT), shown by the IoT-enabled telerobotics application in home care suggested by Zhou et al. (27). In (28), a survey of several telepresence robotic systems reveals three primary applications of telerobotics in geriatric care: telemedicine, remote interpersonal interactions, and telehealth monitoring.

6. Robots During Epidemic Outbreaks

During outbreaks of infectious illnesses, healthcare professionals have a significant risk of infection from direct patient contact. This exposure may be mitigated when robots perform some nursing responsibilities (29). Nursing robots provide similar functions as emergency response robots used in polluted environments, such as those after a nuclear plant incident. In both scenarios, robots serve as primary agents mitigating human exposure to health risks. The COVID-19 crisis in 2020 has sparked a fresh interest in robotic technologies as useful tools to prevent a pandemic. Despite advancements in nursing and service robots, the robotics industry was unprepared to provide effective solutions in the aftermath of the COVID-19 epidemic. An enhanced function for nursing robots has arisen about their capacity to diminish human physical touch and exposure. Numerous robotic applications have been recognized, including autonomous robots used for disinfecting hospital wards using non-contact ultraviolet (UV) surface disinfection technologies, delivering medications, meal trays, and medical supplies, as well as managing contaminated garbage inside a hospital setting. An ancillary advantage is that robots reduce the consumption (and need for reutilization) of personal protective equipment while also preventing contamination during its removal.

In large-scale screening programs, robots may assist in sample collection, minimizing physical touch and enhancing research coverage. Robotic manipulation systems may be used in laboratory testing by automating the processing of substantial sample volumes. Robots may do temperature monitoring in public spaces and entrance points for diagnostic and screening reasons.

The aforementioned functions proposed for assistive robots are also pertinent to mitigating the effects of quarantine and social isolation. Socially helpful robots may provide companionship and maintain social interaction for sick and the elderly when actual visits are unfeasible. Robots may provide physical assistance to the elderly and ill at home, as well as allow health monitoring when family, friends, or

caregivers are less accessible. Rehabilitation treatments may proceed without the actual presence of a physiotherapist, and physical exercise sessions at home or in aged care facilities can be conducted without an instructor. Conversely, mobile robots may monitor social distance regulations in public spaces, verify the application of protective gear, and provide reminders and alarms. Additionally, terrestrial or aerial robotic vehicles may aid in monitoring quarantine zones and border security activities (30).

Furthermore, teleoperated robotic manipulation devices may assist in diagnosis and health monitoring without the actual presence of a medical professional. Telesonography robots, such as those referenced in sources (31, 32), may facilitate evaluations of pulmonary conditions and decrease the risk of cross-contamination in suspected patients. A telerobotic ultrasound system was recently evaluated for cardiopulmonary evaluation of COVID-19 patients, as detailed in Zhou et al. (27).

7. Robots in Healthcare Settings: Concept Case Study Endorsement

Despite established therapeutic benefits and economic prospects, transportable robotic technologies still exhibit low market penetration in hospital settings. This is exacerbated by the limited availability of purpose-driven solutions that fail to sufficiently scale to meet the diverse and substantial demand for healthcare services and logistical activities, hindering broader adoption. Furthermore, manufacturers sometimes underestimate the significance of connecting their solutions with current healthcare systems, whereas robotic fleets are susceptible to cybersecurity threats and generally need time-intensive and expensive infrastructure implementations (33–35). These topics are now garnering significant study attention globally.

8. Conclusions

Robots are now influencing several facets of our life, with their applications beyond conventional uses in manufacturing. Nursing and assistive robotics are under the umbrella of service robotics, which encompasses non-industrial applications of robots. In this regard, autonomous and/or tele-operated robots used in healthcare may enhance productivity without sacrificing quality of treatment while decreasing costs. Their aim also include geriatric care, promoting the aging-in-place idea. Recently, an enhanced function for nursing robots has arisen as a viable strategy to address epidemics of infectious illnesses. The technologies in question are well-established from a technological perspective. Producing effective solutions requires the amalgamation of robotic components (mobile robots, manipulation systems, end-effectors, etc.) with other facilitating technologies (vision and image processing). The current review highlights the potential for nursing and assistive robotics, as evidenced by survey results. Notably, the challenges to be addressed encompass not only technological and clinical issues but also user acceptance. While an overall favorable attitude toward the implementation of robotic technologies was observed, some skepticism was also apparent. Effectively addressing these concerns will be crucial for their future, making informed robot design imperative in this context.

To promote the use of these technologies there exist three axes for targeted action, directed toward the end-users. Firstly, nursing and assistive robotics can become part of the nursing professionals' education, familiarizing and allowing them to effectively utilize these tools but also appropriately present them to patients and older adults. It is important that the capabilities of the robots are clarified and their role is transparent to the users. The second direction is to ensure direct involvement of all stakeholders in the product development stage, with patients' associations engaged in a leading role. Beyond the desirable effect on user acceptance it will eventually result to more efficient clinically-oriented solutions. Finally, wider adoption of nursing and assistive robotics will depend on successful implementations and demonstrations in clinical practice, while keeping in mind that evaluation will be on the basis of healthcare quality and cost effectiveness.g, video streaming, security, etc.). Robotic systems are intrinsically interoperable and may be combined with other modern technologies (e.g., internet of things, electronic health) to enhance their capabilities and facilitate clinical practice adoption.

Despite the promise of nursing and assistive robots, difficulties persist that must be resolved before large-scale practical deployment may occur. Key technical hurdles include robot autonomy, interior navigation,

and safe operation in healthcare environments. These domains need further basic and applied scientific investigation. Ultimately, in addition to technical hurdles, the attitudes and apprehensions of end-users about these technologies will significantly influence future advancements. The latter was the subject of the questionnaire survey given here, consolidating the perspectives of nursing professionals on the urgent topics described below.

The majority of participants saw themselves as technologically proficient, certain in their ability to operate and engage with robots, and capable of instructing their colleagues and patients accordingly. Consequently, it is unsurprising that the same group of respondents expressed enthusiasm for using robotic solutions in their employment. The latter is based on the established assumption that robots would function constantly throughout the day while swiftly reacting to specified duties. Nursing experts expect that the integration of robots in healthcare settings would ultimately reduce the physical strain associated with non-clinical chores, enabling them to focus on their core clinical responsibilities. The results indicated that a significant portion of time is spent on often monotonous, non-clinical activities, including logistics, linen transfers, meal management, and garbage disposal. In such scenario, nursing practitioners mostly felt that patients would also endorse the adoption of such robots. Positive feedback was furthermore documented on the acceptability of robots in consistently executing therapeutic activities (e.g., monitoring vital signs). The majority of respondents feel that patients will respond favorably to the concept of robots doing clinical jobs, provided that healthcare personnel properly facilitate the introduction of the process.

A segment of the population voiced concern about the integration of robots in clinical treatment, citing challenges in persuading patients and training new colleagues. This may be linked to responders' uncertainty over their colleagues' potential support for the revolutionary shift. A notable worry that warrants attention, although not being the dominant perception, pertains to the potential job security threat posed by robotic solutions in the future. In this regard, main user-acceptance issues are to security and privacy.

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استكشاف دور الروبوتات في رعاية التمريض للمرضى كبار السن: مراجعة شاملة

الملخص

الخلفية :مع تقدم سكان العالم في العمر، يزداد الطلب على حلول مبتكرة في رعاية كبار السن. توفر الروبوتات تقدمًا واعدًا في مجال رعاية التمريض للمرضى كبار السن، حيث تواجه تحديات مثل الحركة، والتفاعل الاجتماعي، ومراقبة الحالة الصحية. تستكشف هذه المراجعة دمج التقنيات الروبوتية في ممارسات التمريض، مع التركيز على إمكاناتها لتعزيز جودة الرعاية المقدمة لكبار السن.

المنهجية :أجريت مراجعة شاملة للأدبيات، حيث تم تحليل الدراسات التي تمت مراجعتها من قِبل النظراء والمنشورة بين عامي 2015 و2023. تم البحث في قواعد بيانات مثل PubMed و IEEE Xploreو Google Scholarباستخدام كلمات مفتاحية تتعلق بالروبوتات، ورعاية التمريض، وكبار السن. قامت المراجعة بتقييم التطبيقات الروبوتية المختلفة، بما في ذلك الروبوتات المساعدة، وروبوتات التواجد عن بُعد، وأجهزة التنقل الروبوتية، حيث تم تحليل تأثيرها على نتائج المرضى، وكفاءة مقدمي الرعاية، وتقديم الرعاية الصحية بشكل عام.

النتائج :أشارت النتائج إلى أن التقنيات الروبوتية تحسن بشكل كبير جودة الرعاية للمرضى كبار السن. تعمل الروبوتات المساعدة على تحسين الأنشطة اليومية للحياة، بينما تسهل روبوتات التواجد عن بُعد الاستشارات عن بُعد، مما يقلل من الحاجة إلى الزيارات الشخصية. بالإضافة إلى ذلك، تساعد أجهزة التنقل الروبوتية في منع السقوط وتعزيز الاستقلالية بين كبار السن. وأظهرت الدراسات زيادة في رضا المرضى وتقليل عبء مقدمي الرعاية، مما يبرز القبول الإيجابي للتدخلات الروبوتية في إعدادات التمريض.

الخاتمة :تمثل الروبوتات في رعاية التمريض حلاً قابلاً للتطبيق لتلبية الاحتياجات المتزايدة للسكان كبار السن. يمكن أن يعزز دمج التقنيات الروبوتية استقلالية المرضى، ويحسن نتائج الصحة، ويخفف الضغط على أنظمة الرعاية الصحية. يجب أن تركز الأبحاث المستقبلية على الآثار طويلة الأجل، والاعتبارات الأخلاقية، وتطوير برامج تدريبية متعددة التخصصات للمهنيين الصحيين لتحسين استخدام الروبوتات في رعاية كبار السن.

الكلمات المفتاحية :الروبوتات، رعاية التمريض، المرضى كبار السن، التقنيات المساعدة، التطبيب عن بُعد.