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Robotics in Nursing: A Bibliometric Analysis

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Abstract

Purpose: The purpose of this study was to describe the current evidence found in the nursing literature about robotics used to assist or augment nursing care.

Methods: A bibliometric analysis of published research focused on robotics in nursing care was conducted to analyze the trends of publications. A search of the Cumulative Index to Nursing and Allied Health Literature database was conducted. This analysis was used to determine the types and extent of robotic research presented in nursing and allied health literature, journals that publish robotic research, and the origins of the study.

Findings: Twenty-one articles met inclusion criteria and spanned the years 2004 to 2016. The main disciplines represented by first authors in these 21 articles were medicine ($n = 4$, 9%), nursing ($n = 4$, 9%), and psychiatric medicine ($n = 4$, 9%). Nine countries were represented by the first author. The majority of the specific studies reported using qualitative research methods ($n = 4$, 19%) with reports of other research designs being used. Further analysis of subsequent citations found that 248 subsequent citations were generated from these articles.

Conclusions: The application of robots has been used beyond typical physical day-to-day processes as many definitions of robotics suggest. Eleven (52%) of the 21 articles described the use of robots with aged patients. In some cases, robots were used as companions for older adults, as opposed to replacing mechanical and repetitive motions.

Clinical Relevance: Robotics are being used globally in nursing care areas. While a limited amount of research on this topic in nursing exists, this study of the literature offers reports of applications of robots within nursing care areas.

Intelligent technologies, such as robots, have the potential to positively impact nursing care activities. Robots are virtual or mechanical objects that assist in day-to-day activities or processes. U.S. industries have employed robots since the 1960s, and robots were first used in health care in the 1980s (Kujat, 2010). Various types of robotic technologies aid patient care, including assistance with mobility, administering medications, conducting assessments, monitoring physiologic parameters, and providing companionship (Francis & Winfield, 2006). In addition, the history of robots used in surgery to provide minimally invasive techniques is well established (Cohen, 2017; Hockstein, Gourin, Faust, & Terris, 2007). In fact, surgical robot systems and the industry have seen rapid growth over the past two decades. Fewer robots are dedicated to the nursing field, which begs the question: why are robotics not driving innovations in nursing? Moreover, these technologies have the potential to revolutionize nursing care, yet robotics has received little attention in the nursing literature.

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In an effort to focus on innovations in nursing robotics, this study aimed to examine the current evidence describing the results of research studies using robotics in nursing care areas. The Cumulative Index to Nursing and Allied Health Literature (CINAHL) database was exclusively used because it focuses on nursing literature. The database was searched for literature specific to research reports on robotics used to assist or augment nursing care. To achieve this purpose, a bibliometric analysis of published research was conducted. This analysis was completed to determine the types and extent of robotic research presented in nursing and allied health literature, the origins of the study, and information about subsequent citations.

Background

Concerns within health care such as a dwindling workforce along with advances in technology have created opportunities to explore robotics in healthcare environments. Robotics is a multidisciplinary field using knowledge from math, physics, and engineering disciplines, including mechanical, electrical, and computer engineering (Mesquita, Zamarioli, & de Carvalho, 2016). There are two types of robots. Industrial robots are those that are controlled automatically, are programmable, and may be mobile or stationary. They are often used in industrial settings. Service robots are autonomous and are often found in personal and professional settings (Haegele, 2016).

The field of robotics encompasses the technologies that are used to create robots, for example, building designs and operating or using robots. Robotic technology may be used in surgery, remote monitoring, medication handling, rehabilitative exoskeletons for patients with injuries or recovering from a stroke, and even companionship for elderly (Francis & Winfield, 2006). Robotics innovations are also found in other medical fields, such as pharmaceuticals, biotechnology, and telehealth.

The promise of reducing human errors, reducing costs associated with labor, and improving output efficiency has led to adoption of robotics in assembly lines, agriculture, packaging, and recently health care (Computing Community Consortium, 2016). Health care is unique since many aspects (outside of pharmaceutical and medical device manufacturing) involve direct interaction with patients.

Surgical robots dominate the genre of healthcare robots available, and there are many reviews on the application of robotics in the operating room. Surgical robots, however, still require control by surgeons (e.g., via joysticks), and the state-of-the-art robots claim steadier movements and fewer errors, which results in fewer complications. In fact, some specialty hospitals frequently rely on surgical robots to reduce errors and increase efficiency (Curran, 2016). Other applications of healthcare-related robots include telehealth, specialty hospitals, physical therapy, ambulatory surgery centers, and diagnostic and medical laboratories. The Food and Drug Administration's clearance of a remote presence robot in 2013 led to InTouch Health's dominance of the telehealth industry, which includes telecommunications and video conferencing with mobile robotics to aid in diagnostics. Diagnostic and medical laboratories are switching to fully robotic establishments, eliminating the need for scientific staff (Curran, 2017a, 2017b).

Simulation tools for training in practice and education are prevalent in medical schools and nursing schools. These robots do not interface with patients and most are not fully autonomous or able to react to their environment and make autonomous changes based on sensing their environment. For these reasons, linking the impact of robots used for simulation training to patient outcomes is poorly documented. In fact, only one nationwide study has linked simulation and associated robotic technology to clinical care (Hayden, Smimley, Alexander, Kardong-Edgren, & Jeffries, 2014). The evidence, however, using robotic style simulation training, shows promise to improve training that impacts patient care.

Nursing in particular focuses on patient health and quality of life, which requires specific functions that are outside the scope of many industrial robots. For example, many industrial robots are used to complete repetitive tasks such as manipulating, picking up objects, or assembling devices on a production line. Innovations in nursing robotics have the potential to impact learning outcomes and help nurses to incorporate new methods and tools in their own education and practice. In the scope of this article, robotics in nursing specifically refers to the combination of software and hardware resulting in robots programmed to function independently of humans, yet built or used in conjunction with nurses in healthcare environments. Hence, robotic surgical equipment and telehealth robots are outside the scope of this work.

Bibliometrics

Due to the novelty and limited literature focused on the burgeoning field of robotics in nursing care, a bibliometric analysis was conducted to learn more about the landscape of the literature existing about robotics in nursing care. Bibliometrics is a quantitative analysis of bibliographic information. Many researchers from various disciplines use bibliometrics to improve access to information and to learn more about the structure of knowledge. This method of analysis helps map the development of a field, identify information about key

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information sources used in a field of study, identify new developments in research, and assess research products in terms of productivity, funding, impact, and uptake of information from a geographical perspective.

Bibliometric analysis varies from other types of reviews usually seen in nursing literature such as systematic reviews and integrative reviews. Systematic reviews include quantitative, randomized control trials; integrative reviews include both experimental and nonexperimental research (Whittemore & Knafl, 2005). Neither of these review methods served our purpose to explore literature focused on describing research studies using robotics in patient care areas.

Published scientific literature is the medium whereby members of a discipline communicate theories, research, and findings to support knowledge and translate to practice (Oermann et al., 2008). Advancements within and among disciplines are chiefly recognized through journals that publish research and evidence within their field (Lewis, Templeton, & Luo, 2007). Knowledge about how researchers or scientists use literature, by way of citations in other disciplines and the uptake of literature consumption in different geographic regions, can identify the true impact of a journal and the work it has published.

Metrics available to assist scholars in measuring their research impact and relative importance of their publications are limited. Traditionally, scientific communities have used measures such as journal impact factors and primary citation-based calculations to indicate the performance of scientific journals, but this is not necessarily a reflection of the impact of the published content. Nursing continues to rely on impact factor scores and the reputation of journals, but "nursing can no longer afford to ignore the importance of bibliometrics in nursing scholarship" (Goode et al., 2013, p. 482). Bibliometrics enhances a discipline's ability to showcase its works of scholarship in research, practice, and education. Using such methods is essential to revealing and demonstrating the impact of a field (Goode et al., 2013).

Bibliometric analysis, initially used in library sciences, is an intricate method of including and counting contributions to the literature from a certain specialty area. In this way, library holdings of a discipline's important works are influenced by bibliometrics (Oermann et al., 2008). Rigorous analyses are used to obtain statistics about publications in a specific field, and frequencies can be used to gauge author accomplishments (Goode et al., 2013; Oermann et al., 2008). Further, these studies can clarify how scientific and evidence-based information is being communicated through a discipline. The development of the field, throughout the field, and to other fields can be discovered through exploring citations and citations of authors' work. Information such as where published content has been cited as well as other distinct characteristics related to the dissemination of information in the literature can be revealed by exploring citations (Oermann et al., 2008). Bibliometrics may help advance citation and content analysis by using statistical methods to learn more about the use or impact of a publication in a specific field (Alfonzo, Sakraida, & Hastings-Tolsma, 2014).

Bibliometric analyses may include a simple descriptive signal of productivity such as publication counts. But collaborative indexes, citation analysis, and co-citation analysis may also be included in these studies (Scott et al., 2010). Bibliometric analyses assist librarians in decisions about a discipline's core journals. Librarians may use this information in a cost versus benefit analysis as they determine subscriptions to purchase. In addition, these studies may contribute to impact factor calculations (Oermann et al., 2008). The purpose of this bibliometric analysis is to present results of a bibliometric analysis about robotics used in nursing care. Thus, critical appraisal and synthesis of the literature that would typically be found in other types of review articles are not included in this article.

Methods

A bibliometric analysis was conducted to explore literature focused on research studies using robotics in patient care areas. The initial step in completing the bibliometric analysis was compiling a comprehensive list (Kokol, Blazun, Vosner, & Saranto, 2014) of the eligible articles to include in our sample. The analysis procedure is described as follows.

Step 1

The project team consulted with a medical librarian for the literature search. Three key concepts related to the study were identified: "patient care," "nursing care," and "robotics." An initial cursory literature assessment of robotics in nursing care using both CINAHL and PubMed was conducted. The preliminary PubMed-Medline search revealed that many of the articles pertained to the use of robotics in the operating room, which was not relevant to the purpose of this study, or they did not describe research or analysis of a robotic application in a nursing care area. In addition, some retrievals that met the study criteria were also found in the CINAHL database search. Therefore, the project team decided to use only CINAHL to identify literature for this bibliometric analysis due to its unique coverage and specific scope of indexed literature germane to nursing with comprehensive index of journal articles, conference proceedings, books, and dissertations (McGill University Health Center, 2013).

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A CINAHL database search was conducted in summer 2016 using the three key concepts including CINAHL subject headings and key words in building the search strategy. The database search covered the period of 1981 to 2016, though articles focused on robotics in nursing did not appear prior to 2004. Our search initially yielded 341 references. The search was limited to research articles and publications in English.

Step 2

The project team compiled a comprehensive list of articles meeting inclusion criteria by inspecting titles and abstracts from the search results. Each abstract was reviewed and evaluated by members of the research team to verify contents and determine suitability for inclusion. Of the initial 341 references, 21 were related to robotics in nursing and were retained for analysis. Inclusion criteria were articles that described research studies and results of implementing robotic technology in nursing care areas and those written in English. This bibliometric analysis also examined whether the publication was a research report compared to other forms of published articles, including discussions, editorial letters, and clinical cases. Articles about surgical robots or exoskeletons were excluded.

Step 3

The project team conducted citation and content analysis using EndNote X7 with NVivo to code articles into categories. Microsoft Excel was used to coordinate sorting and descriptive data about articles included. Two of the team members established inter-rater reliability by reviewing abstracts and articles separately, validating the articles included. With such a limited number of articles in the dataset, the team members met to discuss articles in question until a consensus was met.

Step 4

Within the bibliometric analysis, the following measures were used: number of articles per year; number of articles per research method type (quantitative, qualitative, mixed methods); number of publications per country; most prolific authors; most prolific journals; and most cited papers. From each article, common elements of metadata (bibliographic data) were extracted. The extracted data were recorded in a spreadsheet Excel file. Citation counts were collected via Google Scholar, Scopus, and Web of Science. However, an extensive examination of subsequent citations was conducted using Scopus and Web of Science to learn more about the citations of each of the articles included in this sample.

The number of citation counts for each article included in this sample was assessed. In an effort to ascertain depth of impact of the articles, the second phase of this research explored each subsequent citation for each article in this sample. Subsequent citations were followed using the Scopus database. In this way the team could examine where each article in the sample was cited, thereby following the citations through the literature. Scopus was used to track subsequent citations because it indexes more journals than Web of Science. Further, among the three databases (Google Scholar, Scopus, and Web of Science), Scopus has the strongest quarterly increase in the number of papers, citations, and h-index (Harzing & Alakangas, 2016). Moreover, Scopus reports higher citation levels and average numbers of papers per academic across five disciplines (humanities, social science, engineering, sciences, and life sciences). Through researching subsequent citations, insight can be gained about how this literature on robotics has influenced other researchers and disciplines.

Results

Twenty-one articles met inclusion criteria (**Table S1**). A descriptive bibliometric analysis of retrieved articles was performed to analyze the trends of publications related to the use of robotics in nursing care. Given the novelty of the topic, publication dates were not limited in the search. The articles on robotics were published from 2004 to 2016, with the largest number of articles ($n = 3$) published on this topic in 2014.

The disciplines represented by the first author varied in this sample of articles. The main disciplines represented were medicine ($n = 4$, 9%), nursing ($n = 4$, 9%), and psychiatric medicine ($n = 4$, 9%). The first author's country of origin varied and included nine countries: Austria, Canada, Denmark, France, Japan, New Zealand, Norway, Spain, and the United States. The majority of these publications were first authored by someone in the United States ($n = 8$, 38%). However, the most prolific group of authors were from New Zealand. Members from that team published 4 (19%) of the 21 articles. Publications on robotics in nursing were in 18 separate journal titles. The *Australian Journal of Ageing* published the most articles ($n = 3$, 14%) on this topic in the sample. This was followed closely by the *Journal of the American Medical Directors Association* ($n = 2$, 9%). The majority of the specific studies reported using qualitative research methods ($n = 4$, 19%). Other designs reported among these articles included case study, cluster-randomized control trial, exploratory, nonrandomized control trial, observational

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study, pre-post intervention, repeated measures, and survey studies.

The fields of use or applications of nursing robots include aged care, dementia, home care, critical care, intravenous applications, telehealth/education, and rehabilitation. The areas of the most interest and activity include aged care and dementia. Aged care articles focus on attitudes and perceptions, benefits and problems, quality of life, and overall impact on patient care. Broadbent et al. (2016) assessed state-of-the-art robots that take patient vitals, provide entertainment, and gather information via a web browser. The robots communicated with patients and staff via a touchscreen and speech communication. Interestingly, many of those using robots in an aged care setting have a relatively low level of computer experience. An increase in level of experience may drive more nursing robots in aged care applications in the near future.

Robotics with dementia focused on companion robot pets, impact on agitation and depression symptoms, and patient and family perception. Jøranson, Pedersen, Mork Rokstad, and Ihlebæk (2015) assessed a companion robot pet among 60 dementia patients. Nurses who were trained in robot intervention worked with the patients. The results were promising and suggest that companion robot pets in clinical practice may be an effective nonpharmacologic treatment for certain dementia symptoms.

The less active areas of robotic application are in home care, critical care, and telehealth. Home care applications focused on domestic assistance and independent living (Carrera et al., 2011; Fischinger et al., 2016), and one study presented a prototype home care robot (Fischinger et al., 2016). These applications were relevant to aged care but focused on robots in the home instead of a care facility. Critical care applications used telepresence robots to help triage patients (Murray & Oritz, 2014; Rincon et al., 2012). Similarly, telehealth focused on using remote telepresence robots, but in simulated care environments for educational purposes (Sampsel, Vermeersch, & Doarn, 2014). Other applications presented autonomous robotic devices for improved efficiency in intravenous applications (Wood & Burnette, 2012) and compounding applications (Yanav and Knoer, 2013).

Subsequent Citation Analysis

From the 21 articles included in this sample, there were 248 subsequent citations in articles ($n = 128$, 52%), book chapters ($n = 13$, 5%), conference papers ($n = 70$, 28%), editorials ($n = 3$, 1%), reviews ($n = 35$, 14%), and a letter ($n = 1$, <1%). Of the subsequent citations in journal articles, 91 different journal titles from the fields in nursing, medicine, health science, and engineering were represented. Of these journals, 32 (13%) had reported impact factors. The average impact factor of these journals was 2.54 (range = 0.535–5.882). The largest number of subsequent citations ($n = 11$, 4%) were in articles in the *International Journal of Social Robotics* (http://link.springer.com/journal/12369).

These subsequent citations occurred between the years of 2005 and 2016, with the least number of citations in 2005 ($n = 3$, 1%) and the greatest number of citations in 2014 ($n = 61$, 25%). First authors reported in these citations were from a variety of disciplines, such as nursing, medicine, engineering, agriculture, computer science, occupational therapy, pharmacy, and psychology, demonstrating the reach of the articles being cited. First authors of these works were from 36 unique countries, with the majority from the United States ($n = 62$, 25%), followed by France ($n = 29$, 12%).

Of the articles included in this dataset, the most subsequent citations were from the 2004 article titled, "Therapeutic Robocat for Nursing Home Residents With Dementia: Preliminary Inquiry" (Libin & Cohen-Mansfield, 2004), published in the *American Journal of Alzheimer's Disease and Other Dementias*. This article was cited in 38 different articles from the years 2005 to 2016 and had the greatest number of citations ($n = 16$) in 2014. The article was cited by first authors from 20 unique countries, with the most citations from first authors in the United States ($n = 27$). Of the journals in which Libin and Cohen-Mansfield's 2004 article was cited, 32 journals had impact factors averaging 2.54 (range = 0.53–5.882). In addition, this work was cited in other document types such as reviews ($n = 21$), conference papers ($n = 17$), book chapters ($n = 4$), an editorial ($n = 1$), and a letter ($n = 1$). **Figure 1** illustrates the uptake of information from that article within other publications globally.

Discussion

The aim of this study was to assess the current trends in robotics in nursing literature. The most prolific authors, countries of origin, and source titles were identified. Through bibliometric analyses, information about how this topic has been disseminated throughout the field and to other fields was reviewed. While a paucity of research on this topic exists, this bibliometric study in the nursing literature offers reports of applications of robots within patient care areas. Many of the articles in the earlier stages of our search process highlighted robots in clinical care areas but were not research articles. These articles were overviews of the robotic technology and the application of it in the specific care area. Nonetheless, these articles indicate evidence of robots in the clinical

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Figure 1. Geographic distribution of citations of Libin and Cohen-Mansfield (2004).

setting. Overall, limited literature meeting our specific inclusion criteria exists. Within that literature, first authors in the nursing field were also limited to 9% ($n = 4$). However, evidence reveals that robots are currently used in patient care areas and the field will likely to continue to grow (Mordoch, Osterreicher, Guse, Rogers, & Thompson, 2013; Sharts-Hopko, 2014). This inverse relationship of nursing authors to nursing literature suggests the need for more nurse researchers and authors to engage in research on this topic.

Further, the actual application of robots extends the typical physical day-to-day processes. The majority of the articles described robots with aged patients in care environments or home settings ($n = 11$, 52%). In most of these articles, robots were companions for older adults or patients with dementia, compared to robots replacing mechanical and repetitive motions. These findings correlate with review articles on the topic (Mordoch et al., 2013). Other studies in the sample used robots for telepresence in patient care areas, helped monitor medications, and explored how robots may support those in home environments with limited function.

Robotics has global interests based on the findings in this bibliometric study. The most prolific group of authors were in New Zealand. They focused on companion robots among geriatric patients. First authors from the dataset used in this study were mostly from the United States ($n = 8$, 38%), publishing the most articles about robotics in nursing. First authors of articles about robotics were mainly from nursing and medicine. Robotics is still a rich, mostly untapped, resource in nursing. This bibliometric study has demonstrated the potential of robotics in nursing and the valuable analytics that can be described using bibliometric applications to examine literature.

Conclusions

The future outlook for nursing robots is promising. Currently, the main areas employing this use of robots in clinical practice are in aged and dementia care, using companion robots to ease symptoms and improve patient quality of life and outcomes. Although few instances of nursing robots occur in the literature, the opportunity for nursing robots will increase as more tech-savvy people enter aged care facilities over the next few decades.

Nurses, nurse researchers, and engineers must assess the needs of clinical areas and design robots to meet the identified needs. To advance robotics in nursing, engineering concepts must be understood to promote robotics in personal care and to help patients choose the most appropriate type of home technology (Sharts-Hopko, 2014). As more and more nursing robots are adopted into clinical practice, the innovations will drive future enhancements in nursing robot technologies and will inevitably improve the efficiency, quality, and perception of nursing care.

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Clinical Resources

- Computers and robots: Decision makers in an automated world. https://cs.stanford.edu/people/eroberts/cs201/projects/2010-11/ComputersMakingDecisions/index.html
- Georgia Tech Healthcare Robotics Lab. Robotic nurse assistant. http://pwp.gatech.edu/hrl/robotic-nurse-assistant/

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Studies Using Robotics in Patient Care Environments Found in Nursing Literature

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