Towards the Development of Wound Care Robots: An Observational Study Outlining Robotic Design Needs

Zulekha Karachiwalla
Carnegie Mellon University
Pittsburgh, Pennsylvania, USA
zkarachi@andrew.cmu.edu

Ellen Lee
Carnegie Mellon University
Pittsburgh, Pennsylvania, USA
ealee@andrew.cmu.edu

Andrew Dierkes
University of Pittsburgh
Pittsburgh, Pennsylvania, USA
amd323@pitt.edu

Henny Admoni
Carnegie Mellon University
Pittsburgh, Pennsylvania, USA
henny@cmu.edu

Zackory Erickson
Carnegie Mellon University
Pittsburgh, Pennsylvania, USA
zackory@cmu.edu

ABSTRACT

Older adults experience chronic wounds like pressure ulcers at a higher rate than the general population. Because wound care is typically conducted by nurses, the national nursing shortage in the US has a direct impact on the quality of care for older adults. One approach to address this issue is to develop robot assistants that help with parts of the wound care process. However, in order to create such robots, we must first understand what the process of wound care involves. Perhaps surprisingly, there is little data detailing concrete physical and social actions exhibited by nurses during real-world wound care. In this work, we describe data collected from observations of 80 wound care episodes conducted in a hospital or an assisted living facility. We analyze the data to create a taxonomy of wound care interactions and an ontology of wound care tasks.

KEYWORDS

User Centered Design, Wound Care, Robot Manipulation

ACM Reference Format:

Zulekha Karachiwalla, Ellen Lee, Andrew Dierkes, Henny Admoni, and Zackory Erickson. 2024. Towards the Development of Wound Care Robots: An Observational Study Outlining Robotic Design Needs. In *Proceedings of 2024 ACM/IEEE International Conference on Human-Robot Interaction (HRI '24).* ACM, New York, NY, USA, 5 pages. https://doi.org/XXXXXXX.XXXXXXX

1 INTRODUCTION

The World Health Organization (WHO) projects that by 2030, approximately one in six people will be aged 60 or older [10]. As the world's population ages, chronic wounds––disproportionately affecting older adults––will become increasingly prevalent. Chronic wounds impact nearly 2.5% of the US population [7] and cost approximately \$21.4 billion annually [1]. The need for increased wound care complicates an already pressing concern—the nurse labor shortage—which further complicates the delivery of adequate wound care. Nurse staffing shortages have only accelerated in the past decade, with an estimated deficit of nearly 110,000 in 2021 [7]. Multiple studies [4, 5, 9] have shown that better hospital nurse staffing is associated with more favorable patient outcomes, including lower mortality, fewer complications and higher patient satisfaction.

In the last two decades, robotics has emerged as a compelling avenue to address the shortage in the nursing workforce as well as to reduce nurse workload [8]. Integrating robots into the workflow for time-intensive tasks could free nurses to address other priorities, effectively increasing nursing hours per patient without adding staff. In this paper, we look at the potential for robotics in wound care. There is limited understanding of the general process of wound care and how it might be translated into assistive robotic tasks. Our work utilizes a user-centered approach to understand the workflow and task characteristics of nurses performing wound care.

In this paper, we conduct an ethnographic study observing nurses performing wound care in a hospital and an assisted living setting. A total of 80 wounds were observed. We developed a novel training protocol for the observational team and created a note-taking template to record observations. The study involved an iterative coding process of transcripts to identify nurse tasks, needs, and workflow while also deconstructing the characteristics of nurse tasks through a manipulation framework. We collected qualitative and quantitative metrics, including time required for wound care, the distribution of wound types and their locations, the allocation of time across eight distinct wound care steps, and the tasks associated with wound care. From these insights, we present a new ontology and taxonomy for robotic manipulation in wound care.

In this paper we contribute the following:

(1) A wound care data set collected from observing nurses;
(2) A coding schema to identify task characteristics from observational notes; and,
(3) A taxonomy and ontology for wound care through a robot manipulation lens.

2 METHODS

We conducted an observational study shadowing and transcribing nurses behaviors and tasks as they performed wound care. We had two study sites: one hospital and one assisted-living retirement community. At the hospital location, all nurses we observed held Wound, Ostomy, and Continence Nursing Certifications. At the assisted living location, we observed both bedside nurses and

HRI '24, March 11-15, 2024, Boulder, CO, USA

ACM ISBN 978-1-4503-XXXX-X/18/06
https://doi.org/XXXXXXX.XXXXXXX

Certified Wound Specialists. Recognizing the diversity of training among nurses who conduct wound care, we chose to observe at both locations to acquire a more comprehensive understanding of the techniques used in wound care.

Given the nature of this study, we understand that researching wound care and nursing necessitates an interdisciplinary approach. As such, we established collaborations with nursing directors at both observation locations and included a nursing student and nursing professor in our research team. This collaboration was instrumental in providing our team with domain-specific insight throughout training for the observation, during observations, and data analysis of our transcripts.

Prior to undertaking the study, nursing directors educated their respective nurses about the study and subsequently obtained their consent to be shadowed. In this study, we did not collect any patient or nurse personal identifiable information; only nurse behavior and actions were recorded. The Carnegie Mellon University Institutional Review Board determined that this observation was not human subject research.

2.1 Data Collection Preparation

2.1.1 Observation Framework. Our team comprised five individuals who shadowed, and two individuals who coded. The entire research team was involved in developing the code bank. Prior to observation, our team underwent training in wound care to ensure they could document their observations with subject matter expertise. In collaboration with nursing domain experts, we developed a training protocol. As part of developing the training protocol, we needed to categorize specific topics including the classification of wound care steps and wound types. This was important to ensure consistency among team members.

There are multiple Wound classification systems such as the Wagner classification, University of Texas Scheme, PEDIS, and even schemes that are specialty-specific [3, 6]. To maintain consistency within our own work, we adapted from many of these systems to organize wounds into 7 categories: *Ulcers, Pressure, Penetrating, Surgical, Burn, Superficial, and Ostomy.*

Furthermore, the steps to care for wounds also vary by wound type, institution, and specialization [2]. Therefore, we take from multiple systems and categorize them for the purpose of our study into 8 steps: *Introduction, Setup, Assessment, Cleaning, Treatment, Dressing, Removal, and Conclusion.* Once classification was completed, we developed a training protocol for all research members involved in the study. After all training tasks were completed each member was required to watch and take notes on five wound care videos. Once all members completed the training, the team collectively reviewed each member's observational notes on the video until a consensus was reached.

2.1.2 Note-taking Template Development. To facilitate the observation and documentation of wound care practices, we developed a note-taking template for the research team. This template helped to ensure consistency between data collection across researchers and efficiency in collecting relevant data during shadowing sessions. The template included sections to record the date of observation, start and end times of care for each wound, initiation times of specific care actions, wound type and stage (if applicable), wound dimensions, wound location, number of attending nurses, description of observed care, and observer reflections.

2.2 Data Acquisition

In total, we observed 80 wounds: 38 in the hospital setting and 42 at the assisted living facility. Observation sessions ranged in duration from approximately 10 minutes to over 3 hours. This range in observation time can be attributed to variations in the availability of wounds to observe each day. Four researchers conducted the initial round of observations over a period of 10 days at the hospital location. One researcher observed at the assisted living facility for seven days.

2.3 Data Coding

After completing their observation sessions, researchers reviewed their notes within a 24-hour time frame and transcribed them into a formatted spreadsheet. The spreadsheet closely resembled the note-taking template but also included supplementary sections for providing detailed information on each nurse's recorded actions during the observation, such as the wound care step, materials used, and motions performed by the nurse. The supplementary section in the spreadsheet clarified observations for coders, ensuring consistency despite random coder assignments. Subsequently, the researchers uploaded the spreadsheets to ATLAS.ti.

Once the observations were transcribed, the research team developed a code bank in order to analyze the transcripts. We went through an iterative process of code development to finalize our code bank. An initial code bank was developed from coding 10% of the hospital transcripts. We started with a deductive approach by applying pre-defined codes under categories such as: wound care steps, materials, and nurse body parts used. We followed this with an inductive process of open, simultaneous, and pattern coding, 10% of the assisted living transcripts; during this process, coders applied the same deductive and inductive coding methods. Through this process, new codes emerged. New codes were then reviewed as a team and added to the code bank. To ensure both locations were well represented in the code bank, another 10% of transcripts from both locations were coded. Again, using the same deductive and inductive methods, new codes emerged, were discussed by the team, and then added to the code bank. Once the code bank was finalized, two researchers each coded 10% of the transcripts from both locations and tested for inter-coder agreement (ICA). The agreement test yielded an ICA of 0.89 using Krippendorff's α. Given this strong agreement score, we divided the all the transcripts between the two coders to re-code all of the data.

3 RESULTS

3.1 Wound Characteristics

Figure 1 provides a graphical description of the wound types we observed during our study. At both locations, the most prominent wounds observed were pressure and superficial wounds, comprising a combined 65% of our total data set. Ostomy wounds were only observed at the hospital (n=7) while a burn wound was exclusively observed at the assisted living facility (n=1).

Wounds in our dataset occurred in diverse body locations, as seen in Figure 2. The three most prevalent wounds locations were

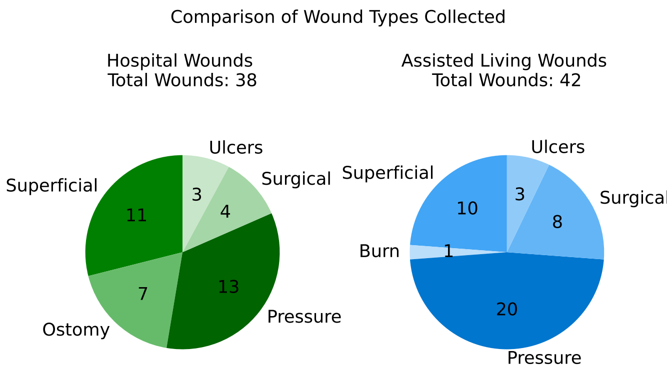


Figure 1: Frequency of wound types in our dataset from the hospital (left figure) and the assisted living facility (right figure).

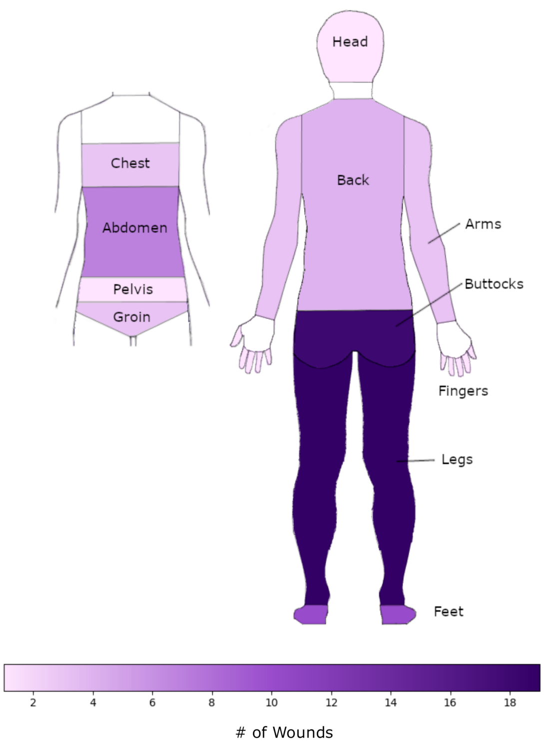


Figure 2: Wound locations in our dataset varied, with most wounds on the legs and buttocks.

the legs (n=19), buttocks (n=18), and feet (n=10), although we observed wounds on many parts of the body. Moreover, within the top three body locations a prominence of pressure wounds is evident, accounting for 51% of the observed cases. This finding underscores a notable concern regarding the prevalence of pressure ulcers in these regions, and a potential area of priority for wound care robotics.

3.2 Categorizing Interactions

Initially, our code bank was designed to identify various components of wound care, including steps, materials, motions (e.g., pushing, pulling, etc.), and tasks completed by nurses (such as moving patients, wiping, etc.). The motions and tasks codes served as crucial codes in unraveling the intricacies of wound care. Using affinity diagramming, we began to group corresponding motions with tasks. Subsequently, we delved deeper into discerning relationships between specific tasks and their classification as either physical or social interactions. This led to the development of our taxonomy and ontology as seen in Figure 3.

Our taxonomy delineates a hierarchical structure of wound care tasks. Initially, tasks performed by nurses are categorized based on interaction types, distinguishing between physical and social interactions. Subsequently, these categories are further subdivided according to the subjects involved in the interaction, including the patient, materials, or assistants. Additionally, accompanying our taxonomy is an ontology that offers a detailed description of tasks associated with these interactions.

3.3 Areas of Support for Nurses

One of our primary aims is to understand where nurses are spending their time and identify potential areas for robots to support. We found that nurses at both locations spent most of their time within the "set up" step of wound care (Figures 4a and 4b). More specifically, nurses at the hospital spent 34% of their time while nurses at the assisted living facility spent 52% of their time doing setup tasks such as gathering materials, prepping materials, and moving the patient. These findings underscore the potential for leveraging robotic assistance, particularly during the preparatory stages of wound care. By automating tasks associated with setup, such as material gathering and patient positioning, nurses could allocate more time to direct patient care and other critical responsibilities.

Furthermore, ulcers (except for pressure ulcers which we classified as its own category for this study) ranked as the most time-consuming wound at the assisted living facility and the second most time-intensive at the hospital. This reveals the burden of ulcer management especially in settings for older populations and the potential for robotic assistance in care. Similarly, surgical wounds ranked as the third most time-consuming wound at the hospital and the second at the assisted living facility.

These results indicates that nurses across diverse healthcare settings dedicate substantial time to managing chronic ulcers and surgical wounds. Developing robots tailored to these prevalent wound types presents an opportunity, as both locations allocate significant nursing resources to their care. Moreover, such robotic solutions can address needs across various healthcare settings where similar wound care is required.

We further aimed to identify the most common tasks performed by nurses during wound care. Our analysis showed that nurses frequently engage in tasks requiring physical interaction with the wound, materials, or the patient. We also observed nurses engaging in social interactions with healthcare professionals, patients, or visitors during wound care. We have detailed the specific tasks and their respective frequencies in Figure 5 and Figure 6.

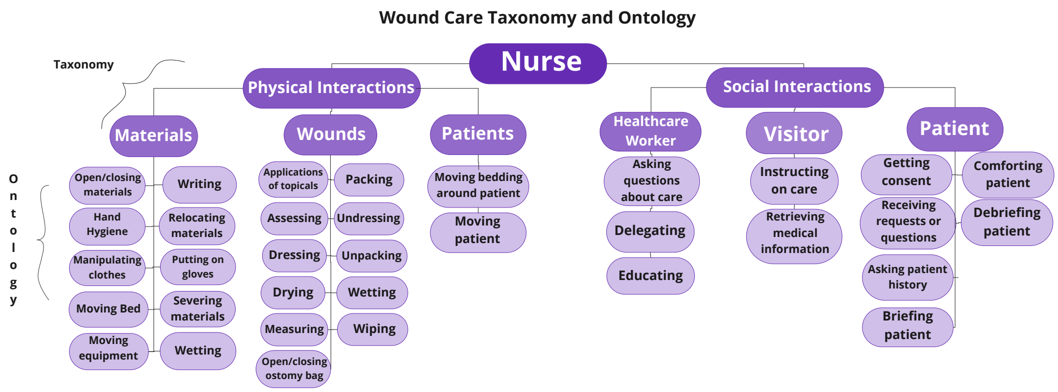
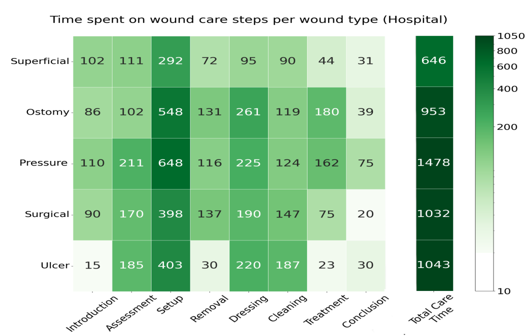
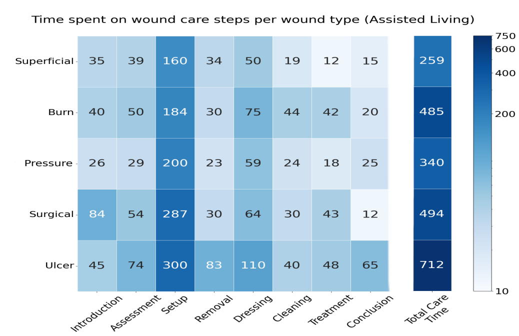


Figure 3: Our taxonomy divides nurse activity into physical and social interactions. Below these, sub-categories are defined based on the objects or people involved in each interaction.



(a) Hospital data



(b) Assisted living facility data

”

Figure 4: Average time spent on each wound care step, separated by wound type. The final column indicates average total time by wound. The color bar is in log scale.

We differentiate between physical and social interactions to analyze their distinct tasks, each requiring unique approaches and more tailored robotic solutions. We found that within the physical interaction category, the smallest count of physical tasks were with the patient (21% at the hospital and 4% at the assisted living). At the assisted living facility, 61% of nurse interactions were with materials, and 35% were with the wound. At the hospital 38% of nurse interactions were with materials while 41% were with the wound.

From our analysis, we identified 21 physical tasks and 10 social tasks done during observations. At the hospital moving bedding was the most prevalent task (n=67), then assessing wounds (n=62), and then moving a patient within physical interactions (n=57). At the assisted living the top three tasks were picking and placing (n=72), dressing (n=56) and opening and closing materials (n=50). These results can inform the most common tasks done by nurses and areas robotics could support.

An intriguing finding, however, is that wound care encompasses not only physical tasks but also social interactions, such as comforting patients and briefing other healthcare workers. This holds importance as it highlights an opportunity for robotic solutions to

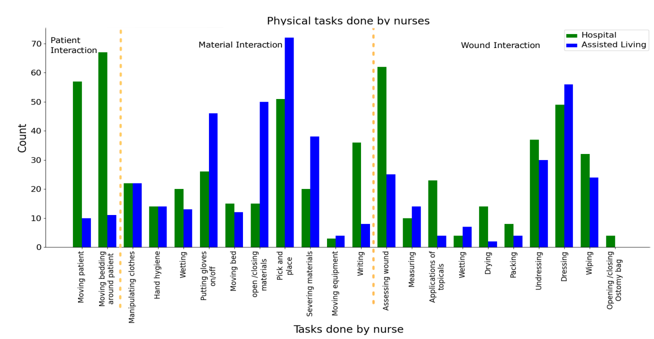


Figure 5: Physical interactions and tasks. Yellow dotted line separates the tasks based off their interaction type

support tasks requiring communication or debriefing among the healthcare team or patients—a task currently handled by nurses, which can be demanding and impact the amount of time spent on caring for the patient and their wound. If robots could assist in improving communication or delegating work, as our data suggests,

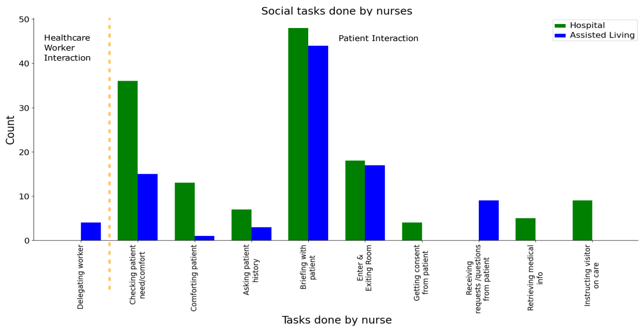


Figure 6: Social interactions and tasks. Yellow dotted line separates the tasks based off their interaction type

this could open up more time for nurses to focus on the actual physical wound care.

Additionally, 13 of the 31 tasks have similar frequencies between the two locations. These results could guide what tasks robots could support across different healthcare settings. Within the social interaction tasks, the three most common tasks at both facilities were 1) Briefing with patient 2) Checking patient need/comfort and 3) Enter and exiting the room.

4 CONCLUSION

Observing nurses during wound care informs crucial insights for designing robots to support healthcare professionals. By observing practices, roboticists can tailor robots to address specific needs, advancing healthcare services.

REFERENCES

[1] [n. d.]. US Wound Care Centers Market. https://www.grandviewresearch.com/industry-analysis/us-wound-care-centers-market.

[2] Sue Bale and Vanessa Jones. 2006. *Wound Care Nursing: A Patient-Centered Approach* (2nd ed.). Mosby Ltd.

[3] Fengning Chuan, Kang Tang, Peng Jiang, Bo Zhou, and Xiaoqun He. 2015. Reliability and Validity of the Perfusion, Extent, Depth, Infection and Sensation (PEDIS) Classification System and Score in Patients with Diabetic Foot Ulcer. *PLOS ONE* 10, 4 (April 2015), 1–9. https://doi.org/10.1371/journal.pone.0124739

[4] Stephen P. Juraschek, Xiaoming Zhang, Vinoth Ranganathan, and Vernon W. Lin. 2019. United States Registered Nurse Workforce Report Card and Shortage Forecast. *American Journal of Medical Quality* 34, 5 (Oct. 2019), 473–481. https://doi.org/10.1177/1062860619873217

[5] Karen B Lasater, Linda H Aiken, Douglas M Sloane, Rachel French, Brendan Martin, Kyrani Reneau, Maryann Alexander, and Matthew D McHugh. 2021. Chronic hospital nurse understaffing meets COVID-19: an observational study. *BMJ Quality & Safety* 30, 8 (Aug. 2021), 639–647. https://doi.org/10.1136/bmjqs-2020-011512

[6] Samson O. Oyibo, Edward B. Jude, Ibrahim Tarawneh, Hienvu C. Nguyen, Lawrence B. Harkless, and Andrew J.M. Boulton. 2001. A Comparison of Two Diabetic Foot Ulcer Classification Systems: The Wagner and the University of Texas wound classification systems. *Diabetes Care* 24, 1 (Jan. 2001), 84–88. https://doi.org/10.2337/diacare.24.1.84

[7] Chandan K. Sen. 2021. Human Wound and Its Burden: Updated 2020 Compedium of Estimates. *Advances in Wound Care (New Rochelle)* 10, 5 (2021), 281–292. https://doi.org/10.1089/wound.2021.0026

[8] Mari Tietze and Susan McBride. 2020. *Robotics and The Impact on Nursing Practice.* American Nurses Association, Silver Spring, MD, USA.

[9] Johanna I. Westbrook, Christine Duffield, Ling Li, and Nerida J. Creswick. 2011. How much time do nurses have for patients? a longitudinal study quantifying hospital nurses' patterns of task time distribution and interactions with health professionals. *BMC Health Services Research* 11 (Nov. 2011), 319. https://doi.org/10.1186/1472-6963-11-319

[10] World Health Organization. 2023. *Mental health of older adults.* https://www.who.int/news-room/fact-sheets/detail/mental-health-of-older-adults