LCBuddy: Towards a Smartphone-based Self-Assessment Tool for Postpartum Patients With Breast Pain

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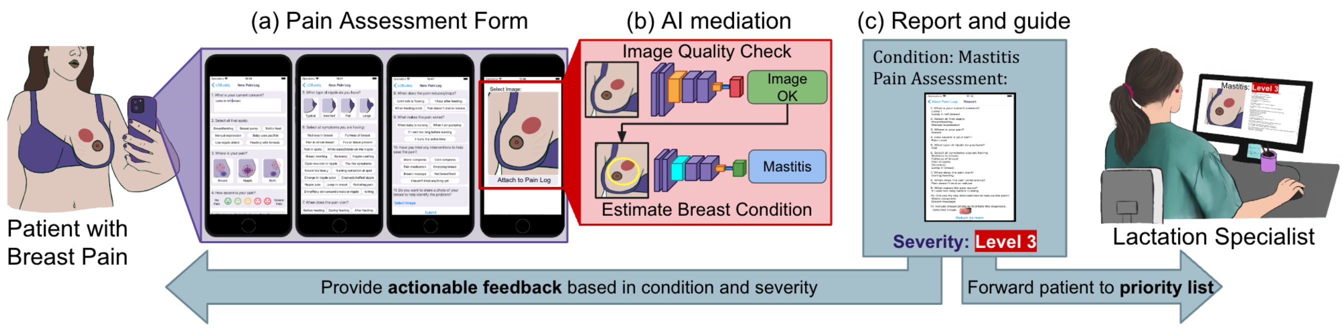

Figure 1: Breast pain is one of the most common reasons for early breastfeeding cessation. Lactation Consultants (LCs) are professionals who help patients mediate their breast pain and solve the issue. Our pain assessment application allows the patient to solicit remote guidance from their medical provider by (a) informing details about their pain (symptoms, pain levels, onset) and providing an image of the affected area. (b) An AI pipeline analyzes the image for a quality check and pre-determines the possible condition of the patient, where (c) the system then reports the image and pain assessment responses to the healthcare provider for easier patient triage based on condition severity. At the same time, it provides the patient temporary guidance to mitigate or reduce the issue while the patient waits for the provider's contact.

ABSTRACT

Telehealth has significantly enhanced various medical sectors, notably in postpartum care, by increasing breastfeeding rates and reducing postpartum depression. However, issues in patient management and triage, particularly in high-demand telehealth lactation consultations, lead to LC burnout, unnecessary costs and diagnostic delays. To address these challenges, this study introduces a pain assessment tool for telehealth lactation consultations, enhancing patient-provider communication through momentary assessment and AI mediation. It features a user interface with image quality assessment and condition classification algorithms, aiding remote diagnosis and triage. The tool guides patients and uses a severity-based feedback system, helping LCs prioritize cases. This method boosts tele-lactation service efficiency, streamlines LC workload, and serves as a model for specialized healthcare triaging. Future work includes refining the feedback system and evaluating the tool in clinical settings to standardize symptom severity grading and estimate its impact, potentially improving expert patient triaging in remote healthcare settings.

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CCS CONCEPTS

• **Human-centered computing → User centered design**; • **Applied computing → Health informatics**.

KEYWORDS

Remote healthcare, telehealth, breast pain assessment, digital health systems, breastfeeding support

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1 INTRODUCTION

Telehealth services have become a regular part of healthcare practice and offer several benefits. These include reducing travel time, balancing provider workloads, increasing the capacity to take on new patients, and enabling faster response times [44]. Key factors influencing the continuity of remote consultations include the user's digital literacy, concerns about privacy and security, and overcoming regulatory barriers [26, 36]. In the domain of postpartum care, telehealth has led to several positive outcomes, such as increased rates of breastfeeding and lower instances of postpartum depression, largely due to better access to lactation specialists such as Lactation Consultants (LCs) [12, 38]. The lack of effective patient management and triage systems hinders LCs' ability to organize schedules efficiently and poses challenges in accurately assessing patient conditions remotely [13, 22]. This often leads to scheduling errors in distinguishing between the need for in-person and remote visits, resulting in unnecessary costs, prolonged interactions, and diagnosis delays [2, 23]. Another issue is the high demand for LCs globally, coupled with a disproportionate ratio of LCs to births. Especially because many LCs combine their practice with midwifery, their time is divided between prenatal visits, childbirth, lactation consultations, and patient management. This intense workload often leads to professional exhaustion, burnout, and emotional stress among LCs [13, 17, 27].

The challenges faced by LCs underscore the need for better tools to support parents, streamline LCs' workloads, and improve care quality [14, 20, 21, 48]. Implementing patient triaging through information systems can be beneficial to optimize this system further as it would allow LCs to prioritize in-person visits for severe cases requiring physical assessments while handling less severe cases and daily checkups remotely [9, 34]. This is crucial for alleviating the workload of these professionals, who often manage a load of patients even when understaffed, and can facilitate faster response to patients [3, 8, 13]. However, a challenge with online LC services is managing the influx of remote messages from patients, which vary in urgency [13, 35]. Consequently, LCs spend significant time manually sorting patient messages to identify urgent cases, which can delay support for mothers with immediate needs. Despite these needs, LCs' current access to remote consultation systems needs more efficient patient triaging capabilities and are not as time-efficient as required, indicating a significant area for improvement in this field.

Previous research has shown the efficacy of using Ecological Momentary Assessment (EMA) [45] for longitudinal monitoring and understanding of maternal behavior for postpartum depression, breastfeeding patterns, and weight normalization post-birth [15, 16, 41]. These studies involved patients recording their symptoms in diaries as part of a retrospective strategy, allowing physicians to evaluate their conditions over a specified time period [45]. However, this retrospective nature of EMA means it's not being utilized for real-time tracking or alerting in postpartum scenarios. This is a significant gap, especially considering the vital need for day-to-day communication between LCs and mothers in the crucial initial days postpartum, which is often hindered by institutional constraints [3]. The lack of a proactive EMA approach to trigger alerts for mothers to seek professional help or inform LCs about patient check-ups is a current limitation in the application of EMA in this field.

This work aims to inform the further development of a patient triage tool for LCs (Figure 1). Our proposed approach involves integrating EMA and AI mediation for a pain assessment tool specifically designed to connect LCs to postpartum patients experiencing breast pain. We present the preliminary exploration, design and development of an augmented patient interface built with valuable expert knowledge to enhance patient information delivery and access by LCs. Following an expert review with an LC who has been a Certified Nurse-Midwife for over 15 years, an International Board Certified Lactation Consultant (IBCLC), and an instructor for future LCs, this paper succinctly reports on the design and development of an AI-mediated system for postpartum patients facing breast pain with three types of patient feedback embedded directly in the user interface, based on the level of severity: (i) actionable feedback based on symptoms for low severity, (ii) prompts requesting more information to determine need for intervention for medium severity, and (iii) forward patient to healthcare provider for high severity. In the long run, we will determine the feasibility and effectiveness of the patient feedback strategies offered in this work. While this work focuses on triaging lactating patients, the blueprint provided in this paper can be utilized for other specialized triaging models. We believe that the insights from our application design and the implementation strategies provided in this paper are general and can be applied broadly to enhance expert patient triaging in healthcare.

2 BACKGROUND AND RELATED WORK

This section examines the intersection of HCI, telehealth, and self-assessment tools in enhancing maternal care, focusing on the challenges and advancements in postpartum health support. It also explores the growing field of tele-lactation services and how momentary self-assessment tools are used to help patients' well-being. Further, it provides insights into how technology is being effectively utilized to improve both the experiences of postpartum mothers and the efficiency of healthcare professionals.

2.1 Advancements and Challenges in HCI for Postpartum Healthcare

The HCI community has several initiatives around postpartum health. Previous works explore breastfeeding simulation through VR for parents-to-be, breastfeeding encouragement through locating safe places for mothers (Feed Finder), milk donation initiatives (Milk Matters), and identifying maternal and family support through technology, showing the importance of finding new ways to support postpartum mothers [4, 46, 47, 50]. These works play a role in educating new parents, encouraging breastfeeding practices, building community, and providing additional resources.

Other previous HCI works highlight the need to provide midwives with tools that allow full patient evaluation and facilitate their work through the digitalization of procedures [18]. Developing technologies for perinatal health includes some challenges, such as physician resistance to adopting digital tools due to providers' limited technological literacy, lack of infrastructure, and the need to include cultural and socio-economic contexts due to diverged approaches and beliefs regarding postpartum health [13, 39]. Despite these challenges, the ongoing efforts in bringing digital systems for these professionals highlights the importance of facilitating the communication between patient and provider for better postpartum experiences and promoting maternal physical and emotional well-being [32, 43], and underscores a global commitment to improving maternal and infant care through technology. Collectively, these initiatives represent a stride in improving postpartum healthcare, demonstrating how technology can empower healthcare providers and new mothers while highlighting the need for adaptation to diverse healthcare environments.

2.2 Tele-Lactation Services for Breastfeeding Support

Lactation Consultants (LCs) are healthcare professionals with expertise in breastfeeding support, including milk production, breast and nipple care, and strategies for managing milk supply post-delivery and upon a mother's return to work. They play a critical role in ensuring that the introduction to breastfeeding is comfortable for the mother and strive to prolong the duration of breastfeeding, ideally beyond six months [10, 42]. The current demand for LCs is high throughout the globe [29], where accessibility to LC services can be challenging due to geographic and financial constraints. Another issue is professional availability itself, since most LCs combine their practice with midwife nursing, splitting their time between prenatal visits, attending births, lactation consultations, and managing their patients, often overloading these groups and being correlated with professional exhaustion, burnout, and emotional stress [13, 17, 27]. Therefore, it is necessary to provide LCs with tools that would benefit both patient and provider, have patients understand instructions, facilitate patient management, and promptly inform patients' conditions more objectively so LCs can directly propose solutions.

The availability of LCs in the telehealth modality significantly impacted mother's lives. In the evolving landscape of maternal healthcare, tele-lactation services have emerged as a significant innovation, offering remote support for breastfeeding mothers [13]. This shift towards digital health solutions is particularly relevant in addressing challenges such as breastfeeding-related pain, a common issue faced by breastfeeding mothers in the early days postpartum that can significantly impact their breastfeeding experience. Breastfeeding-related pain, which can be due to various factors like improper latch, skin conditions, overproduction of milk, or genetic conditions, often leads to early cessation of breastfeeding. Tele-lactation services can help address these issues by providing timely, remote consultation and support, helping mothers overcome pain-related challenges without needing in-person visits [7, 33, 51].

2.3 Applications of Momentary Self-assessment on Patient Well-being

Recent literature underscores the growing interest in applying EMA for healthcare settings, emphasizing its potential to revolutionize patient care and self-reporting methodologies. Some HCI applications combine the methodologies from the medical specialty with interactive assessments in several areas: to enhance the mental well-being of depressive patients [24, 28], to self-assess chronic pain levels for improved patient treatment [1], collecting multiple data for behavior and personal state assessment [30], and to help medical providers understand the daily routines and health needs of older adults with chronic diseases [11]. These applications use numerous form factors: smartphone applications, wearable devices, and voice assistants.

In the domain of postpartum care, digital health solutions include self-assessment tools to support mothers with moderate levels of depressive symptoms [40] and to follow the behaviors of first-time moms to assess breastfeeding patterns within the first few weeks postpartum [15], demonstrating the feasibility to access time-sensitive information in maternal health behavior that is critical during postpartum periods. Although some works identify the potential of using the data collected through the self-assessment forms to aid patient triage [31], no works use these data to approximate patient and provider and bring more timely interventions. Our intent with this application is to benefit from momentary assessments and AI to bring this data efficiently to LCs so that mothers spend less time waiting for responses and can be more proactive when finding solutions to their conditions.

3 METHODS

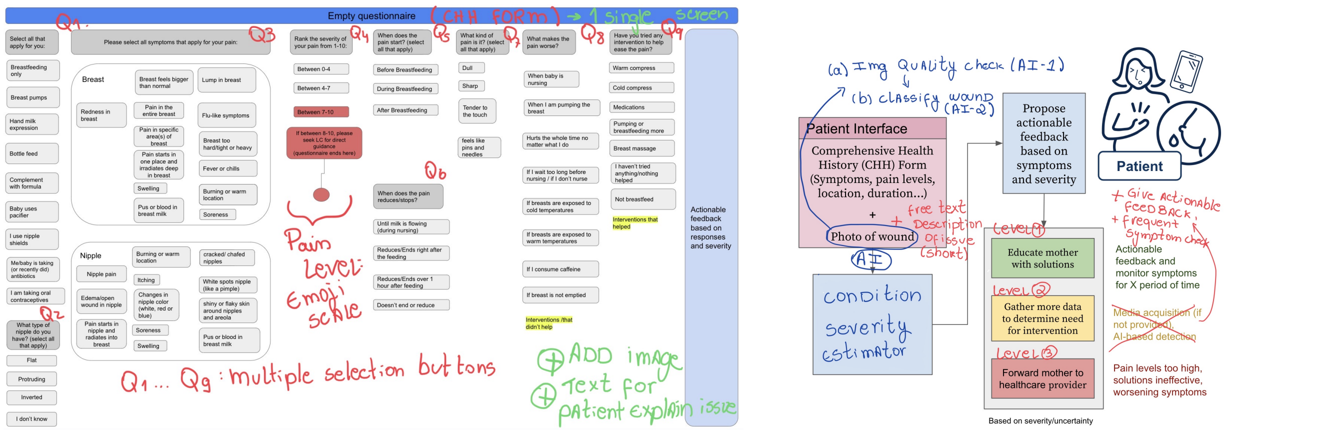
This work builds on our earlier effort [13] that guided LCs in outlining their ideal methodology for solving breastfeeding challenges through tele-lactation services. This section describes the development of an AI-mediated system for postpartum patients facing breast pain, followed by conducting an expert review to evaluate and refine its design and functionality, which consists of two types of studies:

1) Designing a Patient-Centered Application for Breast Pain Assessment — The insights gained from prior research motivated the development of a user-centric application to enhance patient-provider communication. The first step of this process involved a thorough content analysis [25] of existing comprehensive health history (CHH) patient intake forms [6], along with an evaluation of specialized protocols for assessing breastfeeding-related pain [5, 19]. Subsequently, a tailored CHH form was designed specifically for postpartum breast pain cases, focusing on gathering detailed patient information. Additionally, two AI algorithms were developed to compose the application and help faster decision-making: (a) a model that helps the patient take a picture of the pain location following the proper guidelines, and (b) a model that evaluates the picture of the area with lesion and classifies into seven categories (one healthy, and six different unhealthy conditions) to help identify the patient's issue. The data collected from the form, images of the affected area, and the model's results are tailored to assist LCs in effectively triaging patients by evaluating the severity of symptoms. It aids decision-making by determining whether remote or in-person consultations are necessary or suggesting immediate at-home relief measures when appropriate.

2) Iterative Expert Review — To ensure clinical accuracy, content relevance, and compliance with the LCs' needs, in-depth interview sessions occurred parallel to the developing phases of the application [37]. The expert interviewed is an LC who has been a Certified Nurse-Midwife for over 15 years, an IBCLC, and an instructor at the graduate level for future LCs. The participant shared insights and challenges about solving breastfeeding pain issues through tele-lactation consultations. We conducted three interview sessions, equivalent to three hours of interviews, and detailed notes were taken during the expert reviews to ensure accuracy. Figure 2 describes two examples of prototypes resulting from content analysis and expert interviews. We focus on the highly relevant pieces of insights resulting from our analysis (in Sections 4 and 5) and show how they directly motivate our final design decisions.

4 SYSTEM DESIGN AND CORE FEATURES

From the iterations and feedback during the expert review, we learned about the amount of information needed from the patient to solve breastfeeding pain issues and how most conditions share common terms that can be included in the application. Also, we learned about how pictures are used as part of remote diagnosis and the challenges that non-standardized communication channels can pose in tele-lactation consultations. With these learnings in



(a) **(b)**

Figure 2: Two comprehensive health history (CHH) application and system prototypes. (a) A digital form incorporating common CHH questions combined with common responses within the scope of breastfeeding-related pain. Hand-made annotations were added to inform the feedback provided in the questionnaire: Necessary UI components and what is missing in this iteration. (b) A flowchart informing the patient application layers from the questionnaire until the actionable feedback. Including the AI algorithms to assist LCs with image quality checks and pre-classifies the issue based on the image bring more information to the LC.

mind, we designed a patient pain self-assessment application that offers user interface (UI) components and two deep-learning models to assess image quality and detect breast conditions. In its initial phase, the application features three primary screens. The main screen lets users create and view their active pain self-assessment logs shared with their healthcare provider. Additionally, there is a dedicated screen for creating a self-assessment pain log. This screen presents 11 questions for the patient to complete and submit to their healthcare provider. Finally, the third screen summarizes the patient input from the self-assessment pain log.

4.1 UI Design Components

The four main UI components are detailed below and shown in Figure 3.

(a) Scroll View. The expert shared valuable insights regarding prompting the user to several screens versus one long screen to present the pain assessment questions. Using several screens in the assessment would take the participant longer to complete since changing screens would require additional interactions. The scroll view feature wraps the entire screen content to allow vertical scrolling when the content exceeds the screen size.

(b) Text Input. The expert brought the perspective that besides the other questions in the assessment compose a complete evaluation, it is important to give the patient the space to provide their personal view of their reason for contact. The text input, therefore, allows users to input text where they will shortly describe what their problem is and what they are feeling.

(c) Button. The evaluation of the specialized procedures for the management of breastfeeding pain offered the symptoms and descriptive information that arise with the conditions. We translated this information into buttons so that each question can have the answer as multiple selections from the user. From the expert perspective, these symptoms are common among patients facing breast pain, and having them as pre-filled buttons saves time in completing the assessment. Additionally, we used buttons to inform the procedure for taking photos, selecting images, and submitting the assessment.

(d) Image Picker. This component opens the device's gallery or camera to pick an image. We learned from the expert that in remote consultations, sharing images between patients and providers is a common practice for providing context about the location and severity of the case; therefore, this option was included in the pain assessment form.

4.2 AI Algorithms

Previous work informed how remote clinical diagnosis is affected by improper image quality and increased solution time for clinicians and patients[49]. Therefore, we developed a deep-learning algorithm to address the challenges presented by experts in telehealth scenarios, particularly the lack of guidelines and quality checks for patient-provider image sharing in lactation consulting. Additionally, we developed a dataset that categorizes breasts into seven categories to help the system triage the patient's condition. Both datasets consisted of images collected from diverse platforms such as breastfeeding-related books, articles, online blogs for mothers and physicians, YouTube from educative organizations, and social media platforms (e.g., Instagram, Facebook, Twitter) from healthcare providers who would have educative resources for mothers.

(a) Image Quality Evaluation. This algorithm focuses on image quality evaluation. It was trained and validated using a self-gathered dataset with 1024 images containing breast images and upper body

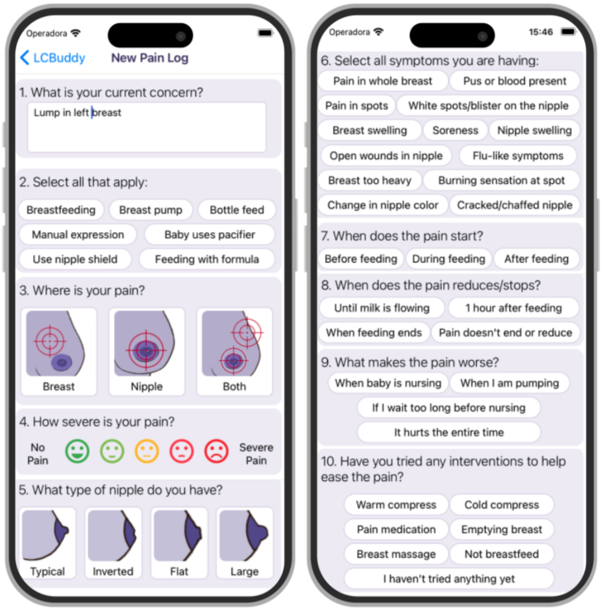


Figure 3: Prototype layout of the patient breast pain self-assessment tool. The self-assessment tool combines existing comprehensive health history patient intake forms with the information covered in specialized protocols for assessing breastfeeding-related pain for lactation professionals.

parts in various conditions, ensuring its ability to assess 9 conditions accurately. Our preliminary results achieved an average accuracy of 98%, with precision and recall metrics averaging 82% and 91%, respectively. This algorithm evaluates the image based on the following conditions: (1) Incomplete: The image does not fully show the breast and nipple, which is necessary for medical evaluation. (2) Nipple Only: The image is suitable for close-up images of nipple lesions. (3) No Breast Presence: The breast is not visible in the image. (4) Extraneous Object: The image has an unrelated object. (5) Over-Exposed or (6) Under-Exposed: The image is too bright or too dark, affecting visibility respectively. (7) Poor Definition: The image is pixelated or blurred, indicating low resolution or focus issues. (8) Taken from Too Far: The image is captured from a distance, which makes it difficult to assess the condition. (9) Breast Visible for Evaluation: The image clearly shows the breast and lesion area, making it suitable for evaluation. If the uploaded image is clear and falls under the 'Breast Visible for Evaluation' or 'Nipple Only' category, it will then be passed to a second model for further analysis. This ensures that only high-quality images are used for accurate pain assessment. In cases where the image does not meet these criteria, users will be prompted to upload a new image that adheres to the guidelines for effective evaluation.

(b) Breast Condition Evaluation. This algorithm classifies images into seven categories related to common breastfeeding pain conditions. It was similarly trained on a self-gathered 1000-image dataset with seven breastfeeding-related conditions, and its preliminary results demonstrated an average accuracy of 92%, with precision and recall metrics averaging 86% and 82%. This algorithm shows promising results for incorporating preliminary diagnoses into the system, guiding LCs in decision-making. The image is classified based on these conditions: (1) Healthy: No visible lesions in breast or nipple tissue. (2) Abscess: Noticeable swelling and redness, with areas of palpable fluid indicating pus collection. (3) Dermatoses: Rash, discoloration, flakiness, uneven skin tone, crusting, or redness. (4) Engorgement: Swollen and red areas, with skin appearing stretched, shiny, and enlarged nipples. (5) Mastitis: Red patches on the breast or nipple, accompanied by swelling, pus, or blood discharge. (6) Nipple Bleb: Small white or yellow bumps on the nipple or areola resembling blisters. (7) Nipple Damage: Swelling or redness of the nipple, peeling or flaking skin, bleeding, or changes in nipple shape. Upon identifying a potential issue through an image, the model will assign its possible condition associated with the self-assessment form to create a severity index for the patient, which helps the LC understand the urgency and severity of the condition. Although some of the conditions are visibly more serious than others, using the self-assessment form helps provide details about the patient's pain levels and symptoms, giving more precise information about the severity of the patient's issue and preventing errors. Users should consult an LC for a thorough evaluation and treatment when a high severity index is indicated.

5 FEEDBACK MECHANISMS

Our self-assessment pain application envisioned three feedback mechanisms based on the severity of the patient's condition as determined by their self-assessment responses. Once the patient submits their self-assessment, an algorithm evaluates the responses and assigns a severity score. This score serves a dual purpose: (1) it informs the LC about the patient's current status, and (2) it provides the patient with immediate, actionable steps to take while awaiting further advice from the LC.

5.1 Level 1: Low Priority

At this initial level, the focus is on self-management strategies that patients can employ at home to temporarily alleviate symptoms. The application offers tailored advice on simple yet effective home remedies or adjustments in daily routines that could help mitigate pain and discomfort. Key features of this level include: *(a) Self-Management Guidance:* Empowering patients with strategies to address minor symptoms at home, fostering independence and confidence in managing their condition. One example of feedback in this stage can include applying heat and breast massage to help alleviate plugged ducts. *(b) Reassessment Reminder:* The application prompts patients to re-evaluate their symptoms within a 6-12 hour window, enabling them to track their progress and identify any changes in their condition. *(c)Low-Priority Alert to LC:* The LC is informed of the patient's status as low severity, ranking it as a non-urgent case together with the guidance suggested to the patient, allowing LCs to prioritize patients based on urgency.

5.2 Level 2: Medium Priority

Patients categorized under this level receive more detailed and personalized feedback. This level signifies a greater need for attention than Level 1 but has not yet escalated to urgent medical intervention. Key aspects of this level include: *(a) Enhanced Actionable*

Feedback: The application provides more specific recommendations tailored to the patient's reported symptoms and their severity. *(b) Frequent Follow-Up:* A shorter follow-up interval is suggested for reassessment (within a 3-6 hour window), ensuring closer monitoring of the patient's condition. *(c) Moderate Alert to LC:* The LC receives a notification marked as medium priority, suggesting that the patient needs a professional response and possible intervention if symptoms persist or worsen.

5.3 Level 3: High Priority

This level represents a critical threshold, indicating that the patient requires immediate professional medical intervention. It is activated when the self-assessment indicates severe symptoms that cannot be safely managed through self-care or delayed consultation. The directives for this level are: *(a) Immediate Medical Guidance:* The application advises the patient to seek prompt medical attention, emphasizing the urgency of their situation. *(b) Direct Contact with Healthcare Provider:* The system prioritizes these cases, moving them to the top of the LC's list for immediate action. *(c) Scheduling Assistance:* The application may offer functionalities to assist in scheduling an urgent appointment or direct the patient to the nearest healthcare facility.

In summary, this three-tiered feedback mechanism in our self-assessment pain application ensures that patients receive timely, appropriate guidance and automated responses based on the severity of their symptoms while efficiently managing the workload and prioritization for LCs.

6 DISCUSSION AND CONCLUSION

This work introduces a pioneering pain self-assessment tool designed for breastfeeding patients engaging with LCs via telehealth. This application plays a dual role: it keeps LCs informed about the severity of their patients' breast pain, and it empowers patients with actionable feedback and provisional solutions while they await professional support. The application's feedback mechanism ensures that patients know their status on the LC's priority list and are equipped with temporary measures to manage their pain. This preliminary interaction lays the groundwork for a more productive and targeted consultation once the patient and LC meet, enhancing the effectiveness of pain management strategies.

We aim to refine the application's feedback system. We plan a co-design study involving LCs to explore the application's functionality in various scenarios. This study will focus on standardizing the severity grading of symptoms and determining the most effective temporary relief recommendations. Furthermore, it aims to establish consensus among LCs regarding symptom severity and appropriate feedback. Finally, a real-world evaluation is planned after the application has been validated. This will involve patients and telehealth providers in assessing how the tool streamlines the workload for LCs and evaluate the efficiency of prioritizing patient contact. This assessment is crucial in understanding the tool's impact on patient care and provider workload management in a telehealth setting.

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