Designing Provider-centered Emergency Department Interventions: A Participatory Design Study

Woosuk Seo, Jiaqi Li, Zhan Zhang, Chuxuan Zheng, Hardeep Singh, Kalyan Pasupathy, Prashant Mahajan, Sun Young Park

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Woosuk Seo[1*] BS; Jiaqi Li[1*] MSc; Zhan Zhang[2] PhD; Chuxuan Zheng[3] BA; Hardeep Singh[4] MD, PhD; Kalyan Pasupathy[5] PhD; Prashant Mahajan[6] MPH, MBA, MD; Sun Young Park[7] PhD

[1]School of Information University of Michigan Ann Arbor US
[2]Seidenberg School of Computer Science and Information Systems Pace University New York US
[3]Department of Human Centered Design & Engineering University of Washington Seattle US
[4]Center for Innovations in Quality, Effectiveness and Safety (IQuESt), Michael E. DeBakey Veterans Affairs Medical Center and Baylor College of Medicine Houston US
[5]Biomedical and Health Information Sciences University of Illinois Chicago Chicago US
[6]Department of Emergency Medicine, University of Michigan Medical School Ann Arbor US
[7]School of Information, Stamps School of Art and Design University of Michigan Ann Arbor US
[*]these authors contributed equally

Corresponding Author:
Woosuk Seo BS
School of Information
University of Michigan
105 S State St
Ann Arbor
US

Abstract

Background: In the Emergency Department (ED), healthcare providers face extraordinary pressures in delivering accurate diagnoses and care, often working with fragmented or inaccessible patient histories while managing severe time constraints and constant interruptions. These challenges and pressures may lead to potential errors in the ED diagnostic process and risks to patient safety. With the advances in technology, technological interventions have been developed to support ED providers in such pressured settings. However, these interventions may not align with the current practices of ED providers. To better design provider-centered interventions, identifying the needs of ED providers in the diagnostic process is critical.

Objective: This study aims to identify providers' needs in the ED diagnostic process by inviting them to participatory design sessions and to present potential design guidelines for provider-centered technological interventions that support decision-making and reduce errors.

Methods: We conducted a participatory design study with ED providers to validate their needs and identify considerations for designing provider-centered interventions to improve diagnostic safety. We used nine technological intervention ideas as storyboards to evaluate the study participants' needs. We had participants discuss the use cases of each intervention idea to assess their needs during the ED care process and facilitated co-design activities with the participants to improve the technological intervention designs. We audio- and video-recorded the design sessions. We then analyzed session transcripts, field notes, and design sketches. In total, we conducted six design sessions with 17 ED frontline providers.

Results: Through design sessions with ED providers, we identified four key needs of providers in the diagnostic process: information integration, patient prioritization, provider-patient communication, and care coordination. We interpreted them as insights for designing technological interventions for ED patients. Hence, we discuss the design implications for technological interventions in four key areas: 1) Enhancing provider-provider communication, 2) Enhancing provider-patient communication, 3) Optimizing the integration of advanced technology, and 4) Unleashing the potential of AI tools in the ED to improve diagnosis. This work offers evidence-based technology design suggestions for improving diagnostic processes.

Conclusions: This study provides unique insights for designing technological interventions to support ED diagnostic processes. By inviting ED providers into the design process, we present unique insights into the diagnostic process and design considerations for designing novel technological interventions to meet ED providers' needs in the diagnostic process.

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Keywords

emergency departments; participatory design; providers; technology; interventions

INTRODUCTION

Emergency Departments (EDs) are dynamic, challenging, and time-critical medical environments in a hospital. In recent years, the increasing need for emergency care services has led to overcrowding [1,2,3], resulting in extended wait times for patients, diminished patient satisfaction [4], and suboptimal patient outcomes [5,6]. With the high volume of patients and staff shortages [7], ED providers face significant challenges in their workflow [3,8]. For example, they often encounter frequent distractions and interruptions from secondary tasks or transitions [9-11], ineffective communication with patients [12,13,14], communication breakdowns, and information loss in the care process [15,16-18], all while being overwhelmed by the intensive patient and teamwork information [19,15]. All these challenges and issues can potentially lead to diagnostic errors [20–23].

Given these challenges in the diagnostic process in EDs, prior work has attempted to implement different types of technology to enhance this process. In particular, clinical decision support systems (CDSS) have been implemented to predict morbidity and mortality [24–27], sepsis [28], adverse prognosis [29], improve triage [30–35], automate clinical documentation [36,37], and predict hospitalization and admission [38–41]. Although these systems enhance providers' decision-making process, many still face barriers to practical applicability and integration into ED workflows [28,42]. For instance, a previous study found that emergency physicians poorly accepted an evidence-based CDSS for evaluating suspected pulmonary embolism because it increased computer time compared to the original workflow, leading to low adoption rates in the ED [43].

One of the main reasons for the failure to adopt and implement effective technological interventions in ED is the limited understanding of ED providers' technology needs and examining appropriate approaches for integrating advanced technologies into dynamic ED workflows [44]. A way to understand the needs of providers is to involve them in the design process [45]. Participatory design (PD) [45] is a methodology that engages all stakeholders in the design process to create solutions that address their needs. Prior work has suggested that participatory and user-centered design approaches can address these concerns [45,46] as they engage all stakeholders in the early stages of the design process, thereby more effectively and promptly addressing user needs and improving the alignment of new technologies with existing workflows [47]. Examples of adopting PD approaches in ED technology development include collaborating with ED providers to design information displays that support awareness and enhance ED teamwork [48] and redesigning the ED patient health information system [49]. Following this body of work, we employed the PD approach in our study to explore potential improvements and technological interventions for the ED diagnostic process, an area previously unexplored using the PD method.

In our study, we explored the following research questions: 1) What are the challenges and needs of frontline providers in the ED diagnostic process? and 2)How should technological interventions be designed to address the specific needs of ED providers? To answer these questions, we conducted interviews and PD sessions, engaging ED providers from different hospitals to identify opportunities for creating user-informed technological interventions and to brainstorm strategies for enhancing the diagnostic process in ED. Our study identified four primary areas for enhancing the diagnostic process in ED: information integration, patient prioritization, provider-patient communication, and care coordination. The findings also highlight the key concerns about integrating advanced technologies into dynamic ED workflows. Lastly, we conclude the paper by discussing design implications for 1) Enhancing provider-provider care coordination and communication, 2) Enhancing provider-patient communication, 3) Optimizing the integration of advanced technology in the ED, and 4) Unleashing the potential of AI tools in the ED to improve diagnosis. This work will ultimately enhance ED care by offering evidence-based technology recommendations and establishing ED-specific design principles for improving diagnostic processes and care.

METHODS

Study Overview

This research is part of a comprehensive initiative examining the perspectives of ED patients and healthcare providers regarding technological interventions to enhance the ED diagnostic process. The broader project aims to develop design guidelines for interventions that address both stakeholder groups' needs. This paper specifically focuses on validating ED providers' needs in the ED diagnostic process and their views on technological support systems. Through six participatory design sessions involving 17 frontline ED providers (nine physicians and eight nurses), we collected and analyzed session transcripts, design sketches, and field notes. Our analysis revealed four key themes that encompass patient needs, coping strategies for common challenges, and design recommendations for future technological interventions.

Design Idea Generation Phase for ED Care Interventions

This PD study is part of a larger research project that aims to study diagnostic errors during the ED care process that involves multiple stakeholders, including patients, informal caregivers, nurses, and physicians. Before our PD study with ED providers, the research team interviewed 17 frontline ED providers (6 physicians and 11 nurses) to better understand their experiences and challenges during ED diagnostic processes. From the interviews, we identified difficulties, emerging patterns of complaints, and general levels of satisfaction with different aspects of the care process (See Table 1). In addition to the known problems, such as ineffective care team communication, ED providers faced challenges in patient assessment and prioritization before triage, decision-making for patient disposition, and high cognitive load among providers. Based on the findings, the research team brainstormed numerous design ideas for each problem category, focusing on frontline nurses and physicians. We then merged the design ideas based on feasibility and usefulness. Finally, we narrowed the list and finalized the nine most effective intervention ideas (See Table 2). Each intervention idea aims to address at least one problem category.

Roles	Problems
Nurses	1. Missed patient reassessments due to demanding clinical workload 2. Limitations in tracking patient reassessment timing and clinical status changes
Physicians	3. Clinician's high levels of stress can impede decision-making and focus on ED work. 4. Physicians' high cognitive load may interfere with their ED diagnosis work. 5. Lack of decision support tools that aid in diagnostic decision-making for increased accuracy. 6. Difficulty for providers to access scattered patient history in a concise and easy-to-read format
Both nurses &	7. Insufficient communication between physicians and nurses about

physicians	orders and next steps in patient care and a lack of EHR support for such communication 8. Insufficient communication between physicians and nurses about the patient's diagnosis and no established opportunity to discuss diagnoses before discharge 9. Lack of notification and information about incoming patients with critical care needs 10. Acuity level differs between nurses and physicians. Physicians sometimes have to reassign acuity levels mentally

Table 1: List of identified problem categories from the previous study's ED provider interview data.

Based on the insights from our interview study, we generated a number of technological intervention ideas by conceptualizing potential technological interventions that could address the challenges identified in the ED diagnostic process. Additionally, we conducted an extensive literature review to understand the status quo, such as the types of technological interventions that had been explored in previous studies and the ED providers' perspectives on adopting technologies in their workflow (e.g., concerns and considerations). These efforts led to the initial generation of over 80 intervention ideas which were then iteratively and collaboratively refined by three research team members and two medical domain experts. This refinement process resulted in the development of nine provider-facing intervention ideas (Table 2). These interventions were subsequently used to inform and guide participant discussions during PD sessions, which we describe in the next section. To visually illustrate each intervention, we create storyboards for the intervention ideas. A storyboard describes an example of a provider facing one or more of the challenges mentioned above and using the intervention to mitigate the problem (See Figure 1 for a sample storyboard).

#	Technology Intervention	Description	Sample of lead question used for the discussion of Patient Need
T-1	Machine Learning Technology for Diagnosis Support	This scenario addresses the need for decision-support tools to enhance diagnostic accuracy. We propose an AI tool that generates potential diagnoses based on patient symptoms and history, aiding physicians in making informed decisions.	Do you wish you would have more time to spend on complex diagnoses?
T-2	Diagnostic Safety Dashboard	This scenario reduces physicians' cognitive load in ED diagnoses. A system generates patient risk scores based on medical data, and an EHR dashboard displays these as color-coded bars (red for high risk, yellow for moderate, green for low), allowing quick prioritization. Physicians can click on a name to access detailed charts.	Do you find it difficult to prioritize patient care mentally based on patient conditions and risk factors?

T-3	Pre-Discharge Team Huddle	This scenario addresses inadequate communication between physicians and nurses on patient diagnoses and the absence of team discussions before discharge. The proposed EHR system flags high-risk diagnoses at discharge, prompting a team huddle to review and finalize the diagnosis, reducing errors and readmissions.	Do you feel that more communication is needed between members of the care team about the patient's diagnosis?
T-4	Visual Timeline of Patient ED Visit	This scenario enhances physician-nurse communication and EHR support by visualizing patient visit timelines. Nurses can access check-in, vitals, PERC score, and CT scan results at the station or bedside, keeping everyone informed about orders and next steps.	Do you struggle to stay up to date on orders and decisions being made for a patient?
T-5	Patient History Aggregator	This scenario enables providers to quickly access comprehensive patient histories through a fingerprint-scanned aggregator, summarizing prior conditions crucial for diagnosis.	Do you find it difficult to review a patient's history in a summarized format, especially when it's scattered across multiple EHR systems?
T-6	EHR-Prompted Diagnostic Pause	This scenario reduces physicians' cognitive load in ED diagnoses. An ED resident inputs a diagnosis in the EHR, which is hidden from a fellow handling complex cases. Discrepancies between their diagnoses trigger a team discussion prompt.	Is there a higher risk of diagnostic error for more complex cases?
T-7	Real-Time EMS Information via Smart Glasses	This scenario addresses unanticipated critical care needs in EDs by using smart glasses. EMTs initiate calls with the care team, sharing real-time patient conditions, allowing the team to prepare for critical care upon arrival.	Do you wish you had more information about when patients are being transferred to the ED, and what sort of preparation is needed?
T-8	Reassessment Reminder Door Flag	This scenario improves timely patient reassessments by using a display monitor outside the patient's room, flashing reminders and showing necessary tasks and medications, helping nurses manage patient care efficiently.	Are you tired of relying on your memory and constantly looking at the clock in order to complete nursing tasks such as patient reassessments every hour or so?

T-9	Stress Management Tracking	This scenario addresses clinician stress in EDs with a tracking device monitoring heart rate and sleep cycles. High-stress alerts enable team leads to manage shifts effectively, ensuring clinicians can take necessary breaks.	Have you ever felt so stressed that you were not able to focus or found it difficult to make decisions?

Table 2: Technology interventions we produced along with questions for participant discussion. Participants were asked to rank them based on their preferences and feasibility.

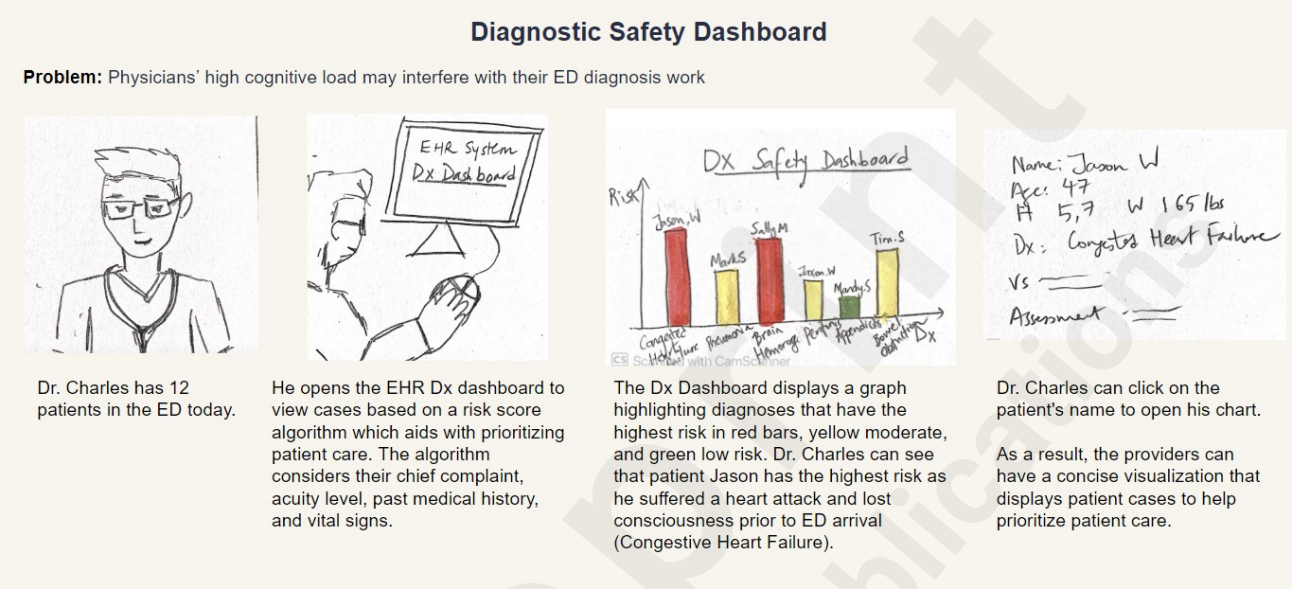

Figure 1: A sample storyboard illustrating how an interactive dashboard for patient risk scores can support the diagnosis process for ED providers.

Participant Recruitment

Participants in the study were recruited from two large healthcare organizations in the U.S. Organization A is a university-affiliated medical institution in the Midwest, and Organization B is a renowned, comprehensive medical center also located in the Midwest. Eligible participants included ED physicians and nurses who had worked in the ED setting for at least one year. A study coordinator contacted potential participants via email or in person on the day of their shift. Once eligible providers expressed interest in participating, we obtained electronic informed consent by emailing the form to them before each session. If participants did not complete the form in time, we provided a paper copy at the start of the session for in-person completion. All participatory design sessions were audio-recorded and transcribed for data analysis. Providers received a $100 gift card as compensation for their participation in a session. In total, 17 clinicians (nine physicians and eight nurses) participated in six PD sessions. This research received ethical approval from the Institutional Review Board (IRB) at the first author's institution.

Session	Format	Affiliation	Occupation	Participant ID	Years of Experience
Session 1	Virtual	Organization A	Physicians	PD-1	20 years

				PD-2	5 years
				PD-3	16 years
Session 2	In-Person	Organization A	Physicians	PD-4	19 years
				PD-5	31 years
				PD-6	2 years
Session 3	In-Person	Organization A	Nurses	PD-7	7 years
				PD-8	15 years
Session 4	Virtual	Organization B	Physicians	PD-9	15 years
				PD-10	26 years
				PD-11	15 years
Session 5	Virtual	Organization B	Nurses	PD-12	8 years
				PD-13	9 years
				PD-14	20 years
Session 6	Virtual	Organization B	Nurses	PD-15	30 years
				PD-16	3 years
				PD-17	2 years

Table 3: Demographic information of study participants for each design session.

Participatory Design (PD) Sessions Procedure

We conducted a total of six PD sessions. Each session consisted of 3-4 participants with the same or similar roles (e.g., nurses or physicians) to mitigate the potential influence of power dynamics on the expression of opinions [50,51]. The participants' characteristics varied in experience, from novices to experts with over 30 years in the field, as detailed in Table 3. The sessions were conducted either in-person or online via Zoom, depending on the participants' preferences and availabilities. We provided colored pens, paper, and sticky notes for in-person sessions, while for virtual sessions, we used slide presentations and Miro board as interactive whiteboards for the participants' design collaboration. Additionally, two to three researchers were present at each session, taking detailed notes.

Each PD session lasted up to 120 minutes and comprised three major parts: intervention idea discussion, individual design, and group design. Specifically, the first part focused on the presentation and discussion of the nine intervention ideas developed by the researchers. After presenting each idea, the researchers used leading questions to assess the perspectives of ED providers (e.g., needs, opinions, perceptions, expectations) for each intervention idea and allowed them to rank the intervention ideas (see Table 2). In the individual design activity, participants selected one or two intervention ideas that most resonated with their needs based on their personal perspectives and professional experiences. After choosing their preferred intervention ideas, they were asked to further improve the design by modifying or adding new elements and features or to design their own new intervention. For the group design activity, participants were asked to select a top intervention idea as a group and work together to synthesize their individual design ideas and develop a final design solution (See Appendix 1 for sample group designs). Participants engaged in discussions on the salient features, pros and cons, and concerns associated with their final group design. Each session was concluded by eliciting participant feedback to improve future sessions.

For the in-person sessions, we captured audio recordings and took photographs of the participants' sketches and designs. For virtual sessions, video recordings were made via Zoom, and participants'

digital creations were also recorded for further analysis. In addition to the recordings, session facilitators took field notes throughout the sessions for data analyses.

Data Analysis

We used transcripts as the primary data source, and all other collected data were used as supplementary sources. Two researchers open-coded the transcripts of the first three transcripts. The researchers transcribed and analyzed features and content from participants' sketches and design illustrations, converting these visual elements into textual descriptions to facilitate thorough examination. Each sketch and/or digital artifact was meticulously analyzed to extract key features, such as design elements, functional aspects, and underlying needs. The codes were compiled into a growing codebook organized by their corresponding intervention or put into a general category. Based on this evolving codebook, the remaining transcripts were then coded. If any new codes were discovered, they were either added to the codebook as a new code or incorporated into the definition of an existing, similar code.

We then utilized affinity diagramming [52] to identify the emerging themes from the codes. Similar codes were first grouped together into sub-themes specific to each intervention. Then, a team of researchers engaged in a series of discussions to build larger, emerging themes that spanned across the different interventions. For example, a larger theme of “Communication among the care team members" contained various sub-themes, such as "piece together information about a patient and keep every care team member on the same page.” Codes that were ambiguous or needed further support were refined by referencing participant quotes from transcripts and participants’ sketches from PD sessions. After multiple group discussions, we identified four themes that describe providers’ challenges in the ED diagnostic process.

FINDINGS

Based on the analysis of collected data, we identified top intervention ideas that participants preferred, four key areas in the ED diagnostic process requiring technological support, and major concerns regarding the integration of advanced technologies into dynamic ED workflows.

Throughout all sessions, participants collectively favored the following interventions to enhance the existing ED diagnosis process (Table 2): T-1: Machine Learning Technology for Diagnosis Support, T-2: Diagnostic Safety Dashboard, T-3: Pre-Discharge Team Huddle, T-4: Visual Timeline of Patient ED Visit. Participants believe these intervention ideas could improve crucial aspects of the ED diagnosis process. Specifically, T-1 could broaden access to comprehensive patient information and reduce potential errors. T-2 might simultaneously manage multiple patient cases, optimize prioritization, and rapidly identify high-risk patients. T-3 addresses communication and understanding gaps between physicians and nurses regarding diagnoses, while T-4 aims to bridge the communication divide and keep patients informed about their care progress.

We also report the key areas of improvement in the diagnostic process, which indicate the challenges faced by providers in the ED diagnostic process. Below, we present four prominent aspects extensively discussed among participants.

Effective Integration of Patient Information for Timely and Accurate Diagnosis

Participants often faced challenges with incomplete, hard-to-find, or misleading patient information, which can inadvertently lead the medical team down an incorrect diagnostic pathway. Incompleteness can result from prehospital providers failing to relay all necessary information at handoff or integration issues among healthcare information systems. Assessing relevant information is problematic when stored using varied and repetitive terminologies or buried in multi-level systems. Misleading information typically occurs with objective data, such as vital signs. For example, external stress or the use of an incorrectly sized cuff can result in elevated heart rates or blood pressure readings, potentially skewing risk assessments.

To access comprehensive patient information effectively, participants mentioned that both historical information (e.g., past medical history, long-term medications, patients' care preferences, and social determinants) and ad-hoc information (e.g., lab test results, vital signs, clinical observation notes) should be integrated to make an accurate diagnosis. For instance, PD-16 suggested how T-5: Patient History Aggregator could be integrated with existing care systems to help providers in the diagnosis process: "*If we could have that [History Aggregator] page already incorporate all the other systems where this patient has received care, I see that as helpful. It's kind of like, in my mind, redefining the chart review tab in a more encompassing form.*" Some participants also highlighted the dynamic changes in physiological values when redesigning the T-1: Machine Learning Technology for Diagnosis Support. To maintain accurate risk assessments, it is critical to continuously update data reflecting the dynamic changes in patient conditions, especially for those critically ill patients whose health status can rapidly evolve. This suggestion showed participants' desire to receive updates about the patient's status for better management, as many patients are coming in and out of the ED.

Some participants suggested that medical information should be displayed in a simple, clear, and efficient manner, such as streamlining all necessary information onto one page to avoid spending time searching and organizing it piece by piece. PD-5 highlighted the importance of information presentation for T-4: Visual Timeline of Patient ED Visit: "*It's information that we just want to be displayed in a more graphic, simpler form where it's not so busy. You open it up, it's one snapshot, and you click on which part of it you want to do now... It's just organized in a better way, in a simpler way*" [PD-5]. PD-5 envisioned this approach would enable healthcare providers to efficiently focus on critical details, such as a patient's historical data directly relevant to their chief complaint.

Optimizing Patient Prioritization to Improve the Triage and Care Process

Another important area to improve is related to prioritizing patients. The current triage process may lead to the improper prioritization of patients with critical needs. Triage in the ED can be influenced by many factors, including triage nurses' clinical knowledge and judgment, the clarity with which patients describe their symptoms, and the availability of patient records or medical histories. Additionally, the Emergency Severity Index (ESI) classification criteria, which classify and prioritize patients based on the severity of their disease and the estimated number of resources needed for their care, can fail to account for dynamic changes in a patient's condition. For example, there is no adaptation of the ESI score despite clear signs that the patient has become more critically ill. For these reasons, there is a risk of patients being misclassified and inappropriately prioritized, which may result in those with severe conditions facing longer wait times.

To address those issues in the triage process, our participants expected the AI-driven prioritization system to analyze various types of information, including contextual (patient's relevant medical history, symptoms), situational (dynamic changes in patients' symptoms, length of waiting time), and human factors (clinician's knowledge and experience). This ensures timely attention to critical cases and improves ESI's shortcomings. For instance, when discussing the idea T-2: Diagnostic Safety Dashboard, participants stated that the algorithm could consider different and comprehensive factors to identify higher-risk individuals, such as those with a history of asthma or cardiac. One participant noted, "*The algorithm looks at the chief complaint, acuity level, and past medical history. I think that helps as well. For example, if it's a younger person with a syncopal episode and you find out they have a previous cardiac history, that would make them a higher risk than, say, a 30-year-old who passed out for another reason. I like how this algorithm considers the whole patient and takes that into account.*" [PD-12]. Additionally, many participants valued the explicit representation of different patient prioritizations through the use of various colors (e.g., red, yellow, green) and symbols (e.g., an alarm bell, a smiley face) since it could enable providers to quickly identify which patients require immediate attention visually.

Enhancing Patient Engagement in the Diagnostic Process

Our participants mentioned that it could be challenging for providers to get timely diagnostic feedback and updates on changing symptoms from patients due to time constraints and heavy workloads in EDs. Providers often rely on brief interactions or one-way communications to gather information which may lead to an incomplete understanding of patients' evolving symptoms. Additionally, patients frequently feel anxious and frustrated due to the lack of ongoing updates about their condition, which can lead to increased complaints and misunderstandings.

Many participants agree that informing patients about the status and progression of their care could help manage their expectations and alleviate anxiety. They expected patients to feel reassured that providers would still take care of them when patients understood the next steps in the diagnosis process. PD-2 stated that when discussing the idea T-4: Visual Timeline of Patient ED Visit, "*The patient can visualize what's been done and what they're waiting for. It sort of wards off that sentiment of, 'I went to the ER, and they didn't do anything,' and also gives them an idea of what the next step is*". By sharing the ED process steps, participants anticipated more patient engagement and having more time to focus on effective patient communication.

Participants mentioned they want easy-to-use tools to help get more accurate, timely updates directly from patients to aid the care process. Nurses' work could be expedited by having patients more actively involved in their care and providing information. For example, participants suggested that the idea T-8: Reassessment Reminder Door Flag could include a feature allowing patients to undertake a self-reassessment of their current condition and medication reactions and relay their results and updates to nurses, potentially via an automated prompt and chat system on a tablet or phone. If a nurse records the administration of fentanyl at noon, the system might automatically inquire about the patient's pain levels twenty minutes later. Then, patients could interact with the nurse, who can gauge the treatment's effectiveness. "*I wonder if there's a way for the patient to enter a self-reassessment like they have their own little iPad and can share how they're doing, whether the pain medication helped their pain rating... it gives the patient the opportunity to provide feedback*" [PD-9].

Our participants also mentioned that engaging patients in diagnostic discussions could be crucial to

reducing potential diagnostic errors. This could allow providers to elucidate the logic behind a diagnosis, articulate how tailored care plans were developed for individual patients, and seek the patient's perspective regarding the proposed plan. In addition to the illustrated functionality of increasing care team communications to reduce diagnosis errors from ideas T-3: Pre-Discharge Team Huddle and T-6: EHR-Prompted Diagnostic Pause, participants suggested empowering patients to contribute supplementary information and express different viewpoints that might not have been considered, to reduce diagnosis errors. For instance, PD-3 emphasized that patients should have the opportunity to share their perspectives on providers' reasoning as a way to promote patient engagement in diagnostic dicussions: "*If the patients heard the diagnostic reasoning, you [clinicians] would be giving them an opportunity to correct you [clinicians]*".

Care Coordination among the ED Team Members

Through the sessions, we identified that the ED care team faces two main communication issues. First, each member of the ED care team has only partial information, leading to a disjointed and fragmented understanding of the patient's case, primarily due to interactions at different stages of care. Patients move from one provider to another, and no one fully knows all the details of the patient's condition. Furthermore, its interpretation can differ even when information is consistently shared among team members. This variation in understanding can be attributed to individual backgrounds, areas of expertise, or perspectives. Second, physician-to-nurse communication could sometimes become ineffective, especially regarding discharge and diagnostic reasoning information. For example, physicians sometimes fail to communicate the rationale behind diagnoses, orders, or care plans to nurses. This issue can impede nurses' understanding of physician decisions and their ability to respond accurately to patient queries.

All participants agreed on the importance of maintaining a consistent and uniform understanding among care team members, especially for complex patient cases. Engaging more care team members in discussions could be advantageous. When discussing the idea T-3: Pre-Discharge Team Huddle, participants noted that it would offer an excellent opportunity for comprehensive information gathering from different team members and roles to minimize potential errors. One participant highlighted, *"You would get everyone on the same page and give the patient a chance to ask questions. At the last minute, if someone asks, 'Well, what about this, or what about that?' everyone is on the same page, which I like"* [PD-2].

Most of the physicians and all nurses mentioned the need for physicians to communicate more detailed information with nurses, including the reasoning behind diagnoses, orders, and care plans, to enable nurses to maintain a comprehensive understanding of the overall situation. When discussing the idea T-4: Visual Timeline of Patient ED Visit, physicians believed that this technological intervention could be instrumental in keeping nurses informed about care plans and the rationale behind physicians' orders in a timely manner. This enhanced, transparent communication could empower nurses to answer patients' queries more effectively, reducing the need for ambiguous or non-committal responses. Nurses, in particular, advocated this because they wished better to explain physicians' orders and diagnoses to patients, as one participant noted: *"Sometimes I go into the patient room and say, "I think they [the physicians] ordered this because they're probably looking to see if you [the patient] have this issue. It would be nice to say confidently, they ordered this because they're looking to see that you have this issue."* [PD-8]

Among our participants, some care team members might hesitate to point out potential errors, from junior members to senior members or nurses to physicians. For example, nurses might be reluctant to bring up potential diagnostic errors to physicians due to a perception that physicians, being more

knowledgeable and experienced in diagnosis, are responsible for treatment decisions. However, the participants believed that some technologies, acting as second opinions, might help address the power dynamic issue. For example, when discussing the idea T-1: Machine Learning Technology for Diagnosis Support, nurses expressed that the list of diagnoses generated by machine learning tools could empower them to engage in discussions with physicians regarding potential misdiagnoses significantly when the physician's conclusion deviates from the algorithm's suggestion: "*It [the machine learning technology tool] also brings up good discussion points with the physician...why are we pursuing this route...or why we're deviating from a particular diagnosis.*" [PD-14].

Concerns of Integrating Advanced Technologies in ED

Our nine intervention storyboards described how emerging technologies can potentially be design to support the ED diagnostic process. While the storyboards were primarily used to validate ED providers' needs, the storyboards also brought discussions about potential issues of integrating such technological interventions. This section presents participants' concerns regarding integrating advanced technologies in ED, including the safe use of AI, privacy, and the additional cognitive and operational workload.

Safe Use of AI-empowered Clinical Decision Support Systems

With growing application of AI techniques in healthcare, more than half of our intervention ideas were inspired by AI-empowered tools. Thus, many participants expressed concerns about the AI's potential inability to consider different care contexts and individual nuances of each patient case in analyzing and presenting various information. This concern was mainly raised during group design activities on several AI-driven interventions such as T-1: Machine Learning Technology for Diagnosis Support, T-2: Diagnostic Safety Dashboard, and T-4: Visual Timeline of Patient ED Visit. Participants particularly mentioned that the same test result can be interpreted differently based on the context. For instance, a particular urine analysis result can indicate different health conditions depending on whether the patient has a positive or negative ultrasound result: *"The same urine analysis result means something totally different if you tell me that the patient has an ultrasound that's clearly positive than if they have an ultrasound that's clearly negative, and it can have the exact same result. And that's the problem. It comes in context."* [PD-4]. Participants suggested that AI systems should account for various factors and contextual cues, such as interpreting test results with other diagnostic information and medical history. However, it may not fully match human providers' ability to perceive subtle cues and insights, which could be beyond the scope of computers or artificial intelligence systems. Additionally, participants suggested that the AI systems should apply different weights to different diagnostic factors (e.g., lab results, medical history) since certain factors weigh more than others, or the system should adjust weights based on dynamic emergency severities when calculating risk scores.

In addition, participants underscored the imperative need for rigorous testing and validation before implementing any AI tool in their existing work practice. They believed that an AI tool must prove its reliability and efficacy to gain the trust of medical providers: *"Critical for it to be, the tool really has got to be tested and robust before it's implemented. Otherwise, no one's going to entertain the idea of adopting it because it's just going to create extra work without perceived value"* [PD-10].

Participants also expressed concerns that an overreliance on technology could potentially lead to a

degradation of human clinical skills and emphasized the balance between such emergent technology use and human skills. For instance, when discussing the idea T-1: Machine Learning Technology for Diagnosis Support, there was a worry that providers might depend too heavily on technology and neglect their assessments. PD-13 expressed her concern about potential overreliance on AI-tools: "*The only concern I can think of right now is … becoming too reliant on AI… If any residents or doctors would start to rely on it too much...you'd hope not, you'd hope they do their own assessments"* [PD-13]. As a potential solution to mitigate such overreliance, some participants suggested that they would like to incorporate AI-powered Clinical Decision Support Systems into their on-the-job training. This integration could allow ED providers to learn from these tools and understand how to collaborate with them effectively without overly relying on AI outputs while maintaining their clinical assessment skills.

Privacy Concerns Toward Emerging Technologies

Participants repeatedly mentioned privacy concerns related to new advanced technologies. They raised issues about potential violations of HIPAA (Health Insurance Portability and Accountability Act) and patient confidentiality, emphasizing the need to ensure adherence to patient privacy laws and regulations. For example, T-5: Patient History Aggregator allows easy access to patient history by scannning patients' fingerprints. Many participants expressed concerns about collecting sensitive biometric data (i.e. fingerprints) from their patients. PD-16 particularly brough the issue of data storage that may lead to privacy outbreak: *"If it is based on fingerprint, where is the information being housed? Is it a cloud database? That is universal? Is it an extension of the electronic health record? Where does it belong? I think it will be a question."* Participants' such conerns about privacy

Extra Workload and Burden to Make Technology Fit into Their Existing Workflow

Participants raised concerns about the potential of certain technological implementations interfering with the established ED workflow, possibly producing extra waiting time for patients and adding extra cognitive and operational workload for providers. One notable instance was during the discussion of the idea T-3: Pre-Discharge Team Huddle. Some participants expressed that integrating such a system could inadvertently delay or create a backlog in the patient discharge process. Given the current ED workflow, it could be challenging to convene all care team members due to their individual duties and potential busyness. A participant [PD-2] explained this concern by stating, *"When you have a patient who is itching to get out the door [being discharged], and you say, 'while we're waiting for this person to show up or we need this other team member [to discuss again],' it can create a lot of delay and backlog if now you have to round to discharge everybody."* Another example arose during the discussion on the T-6: EHR-Prompted Diagnostic Pause. It highlighted concerns that its implementation could disrupt the typical ED workflow by introducing a "parallel" evaluation process. In this context, "parallel evaluation" means multiple providers might independently diagnose the patient, leading to repetitive and time-consuming efforts. This could result in a prolonged diagnostic process and potentially delay treatment. *"I think the scenario would require a change in our current flow, where it's sequential in terms of evaluations that are done of a patient...To one where there's a parallel evaluation, which I think becomes very inefficient and for a patient, can be quite redundant as they have to repeat the story multiple times."* [PD-10]

DISCUSSION

Our findings show that the ED diagnostic process can be improved into four main areas: information integration, patient prioritization, provider-patient communication, and care coordination. We also summarized the key concerns of ED providers in integrating advanced technologies in the ED, including the safe use of AI, privacy, and the additional cognitive and operational workload. Drawing from these findings, we discuss potential design implications of future ED-centered intervention tools for improving the ED diagnosis process.

Design Implications

Creating Standardizing Communication Procedures

We observed that there is significant demand for improving communication between ED providers (the idea T-3: Pre-Discharge Team Huddle was ranked third by participants, and T-4: Visual Timeline of Patient ED Visit was ranked fourth by participants). Information sharing between ED physicians and nurses is often inadequate, limiting nurses' comprehensive understanding of patient conditions. Additionally, varying levels of understanding about the patient exist among different stages in the care team, further complicating the communication process. These findings highlight the importance of establishing standardized communication procedures to ensure a unified understanding of patient conditions among team members. ***We suggest creating more standardized communication procedures in future technical tool designs***. Building on previous insights from the design of digital checklists for trauma resuscitations [53], we recommend implementing an automated checklist system that includes critical patient information such as diagnosis, medication orders, and care milestones. This checklist should be integrated with a timeline that automatically captures details of when each piece of information was added and when actions need to be taken, ensuring all team members are aware of current in-progress and upcoming responsibilities. Additionally, structured communication features such as mandatory read-backs of critical information, regular briefings at shift changes, and digital alerts for key updates can further enhance understanding and collaboration. Such tools are particularly helpful for nurses, who often coordinate various aspects of patient care and benefit from clear, concise, and timely information to make informed decisions and provide the best possible care. This potential application direction also echoes the previous study on the necessity of applying new technological communication interventions to simplify communication among various roles within the ED [54].

Incorporating Technology-Based Second Opinions

We identified power dynamics as a critical issue in the diagnostic process. Such skewed interactions are prevalent between junior and senior members, as well as between nurses and physicians. Hesitation in pointing out potential errors and reluctance to accept feedback is not uncommon, and it could have severe consequences (e.g., increased incidence of medical errors and significant patient safety risks) in fast-paced and critical medical fields like ED [50,51]. Although more collaborative approaches, such as education and mentoring, have been proposed to address the issue of power dynamics [55], we found this issue has not yet been fully resolved. Notably, our findings indicated the potential of technological interventions in mitigating these power dynamics. For instance, the

timeline in idea T-4: Visual Timeline of Patient ED Visit could allow nurses to understand the rationale behind care plans, enhancing their ability to communicate with physicians actively, thus promoting equal and open communication within the team. Also, as mentioned in idea T-1: Machine Learning Technology for Diagnosis Support, second opinions generated using machine learning tools could boost the confidence of junior physicians or nurses in discussing potential misdiagnoses with senior members or physicians in the care team. This echoes and expands on past research [56] about the second opinion in physician-patient relationships, demonstrating it to be an effective way to promote open, positive communication and to enhance satisfaction with clinical decisions. ***By providing second opinions and facilitating information sharing, technological interventions could help overcome the barriers in the traditional power structure of medical roles, potentially improving overall care quality and patient safety.*** Future work could involve designing and implementing such information tools in ED settings to evaluate potential impacts on the ED diagnostic process. For example, in the new ED medical display system, each team member could autonomously select CDSS reports that automatically highlight decision details differing from the primary physician's, with junior members and nurses also accessing these for reference and discussion as a second opinion.

Empowering Patients with Information Transparency

We found a demand for improved communication between providers and patients through timely information sharing, transparency with patients, and patient empowerment. Previous studies show that insufficient communication between patients and providers in the ED leads to dissatisfaction with their care and potential diagnosis errors [12,57]. Factors contributing to their communication issues include patients' and providers' conflicting perceptions of the ED, a lack of patient information, and physicians' diagnostic time pressures [12,57,58]. Our study further reveals the specific manifestations of insufficient communication in the ED between patients and providers: 1) Patients are not fully informed about the treatment process; 2) Lack of opportunities for patients to provide feedback and update their conditions to providers actively; 3) Absence of processes for joint decision-making and care planning between providers and patients, as well as effectively involving patients in diagnostic discussions. These communication deficiencies can lead to patient anxiety and an increased risk of misdiagnosis. Therefore, ***we suggest that future technological interventions should focus on enhancing timely information sharing and transparency with patients and significantly empowering patients' agency. This involves promoting active patient participation in communication, even in joint decision-making and care planning.*** Previous research [59] discussed a digital ED waiting room history-taking tool that utilizes reasoning engine functions to gather patient information. It has been proven to improve communication and understanding between patients and providers. Building on this foundation, we suggest developing a mobile application that allows patients to promptly report changes in their symptoms or express concerns using real-time data reflecting their current condition and personal feelings during their ED visits. The application would also integrate features that encourage patient involvement in diagnostic discussions. Such features could include a symptom timestamp for patients to log details of their symptoms as they occur and a communication chat window that allows for direct dialogue with providers.

Optimizing Advanced Technology Integration in the ED

Our research highlighted specific considerations for integrating advanced technologies into the ED context: minimizing additional workload and cognitive burdens for providers and utilizing high-

fidelity simulations. Unlike other general clinical practices where there is more time to adapt and use new technology, our findings indicated that providers in the fast-paced ED environment may not have the time to try out, thoroughly examine, and use these technologies. They were also reluctant to change their existing workflows to accommodate new technologies, fearing the risk of additional workload. During the design of information displays, our providers preferred concise and practical interfaces, capturing essential information immediately rather than increasing their cognitive load by requiring them to understand the meaning of every icon and content. Additionally, participants considered the idea T-6: EHR-Prompted Diagnostic Pause ineffective and redundant, despite its merit of catching potential diagnostic errors, as it does not fit their existing workflow. Similarly, during the discussion of the idea T-3: Pre-Discharge Team Huddle, participants acknowledged the critical need for care team members to be on the same page regarding information-sharing upon patient discharge. However, they still harbored concerns that the intervention would not align well with their current workflow or the realistic situation where patients would not want to stay longer and wait for a re-evaluation before their discharge. Therefore, building on previous research that emphasized the need for efficiency in the design of ED technological interventions [60], we recommend that future designs and implementations of ED technological interventions consider the fast-paced, high-pressure nature of the ED. This involves ***prioritizing efficiency and focusing on avoiding additional workload and cognitive burdens for each provider***. For example, AI-driven decision support tools should be overseen by designated care team members who monitor AI-recommended diagnostics and conduct departmental audits and custom improvements to reduce the burden for individual ED providers. Similarly, designing interventions like the idea T-3: Pre-Discharge Team Huddle should minimize the potential for increasing workload. Instead of prompting the care team to initiate a team huddle to reevaluate, the design should allow members to quickly review summary reports in the EHR to identify potential issues with minimal additional effort.

From a methodological perspective, we also recommend building on existing ED workflows using methods such as "group workshops" similar to PD or "high-fidelity team-based simulations" conducted in clinical scenarios [63,64]. These methods could ***allow ED team members to experience new technologies and foresee how they can be implemented in their existing work practices while gathering feedback.*** High-fidelity team-based simulations have been widely used in the ED for effect evaluation and training, such as improving communication among ED provider teams [61] and detecting latent safety threats in critical patients [62], proving very effective. Therefore, we suggest extending this approach to introducing new technologies in the ED to guide the integration of new advanced technologies.

Unleashing the Potential of AI Tools in the ED to Improve Diagnosis through Multi-Dimensional Information and Dynamic Patient Data

Our research highlighted a strong demand from our participants to unleash the potential of AI tools in the ED to improve diagnosis further. We found that participants highly valued the top two AI-related ideas (T-1: Machine Learning Technology for Diagnosis Support and T-2: Diagnostic Safety Dashboard) because of the potential to 1) integrate a broader range of comprehensive patient information and perform multi-dimensional data analysis, and 2) facilitate dynamic prioritization and resource allocation. Although there are multiple existing AI applications in the medical field, many of them lack consideration of multi-dimensional information and dynamic prioritization [65] and thus do not fully unleash the potential of AI. To best leverage AI tools in future ED settings, ***we suggest that when designing algorithm development for ED, the input information for these algorithms should be multi-dimensional and incorporate dynamic patient data.*** These algorithms

should be capable of continuously monitoring and evolving based on real-time patient data and feedback, which can aid in enhancing diagnostic accuracy and dynamically adjusting treatment protocols. For example, when designing AI tools for patient prioritization, it is crucial to implement a system that categorizes patients based on initial information and also updates its prioritization as new data become available (e.g., lab results or vital signs). This approach could ensure that resources are allocated promptly to patients with escalating needs.

Limitations

A few limitations of this study should be noted. First, one of the primary limitations of this study relates to the representativeness of the participant sample. Participants were recruited from only two large healthcare organizations in the Midwest region of the United States. While these organizations serve millions and can offer significant insights, this sample may not fully encapsulate the diversity and range of experiences of ED providers worldwide. There might be differences in healthcare systems, cultural contexts, and operational protocols in EDs across different countries or regions. Another limitation of this research is inherent in the study design, particularly regarding the PD sessions. Each session was constrained to a duration of around 120 minutes. This limited timeframe could have impacted the depth and extent of interaction among participants, potentially affecting their comfort levels and the quality of their responses. Participants might have required more time to fully engage with the material, express their thoughts, and collaborate effectively, influencing the innovation and creativity aspects of the session outcomes. Furthermore, some PD sessions were conducted in a virtual format. While virtual sessions offer flexibility and can include a broader range of participants, they might lack the richness of interaction found in face-to-face settings. Non-verbal cues, ease of spontaneous conversation, and the organic development of collaborative ideas are often diminished in virtual environments. The potential limitations in participant interaction and engagement due to the virtual format of some sessions might have affected the overall effectiveness and output of these PD sessions. Last, our study is limited by not presenting functional systems but merely asking participants to imagine how the system works. Without seeing or interacting with a system, eliciting comprehensive user feedback could be challenging.

CONCLUSION

This work presents opportunities for improving ED provider-informed technological interventions and strategies for enhancing the diagnostic process in EDs. Our study identifies crucial enhancements in information integration, patient prioritization, provider-patient communication, and care coordination. The findings underscore key concerns about integrating advanced technologies into EDs. Based on these findings, this work discusses implications for designing future ED technological interventions, from enhancing communication to optimizing the integration of advanced technology and unleashing the potential of AI tools. Future efforts should further apply and test these design suggestions in real ED settings, or continue using improved PD methods with functional systems that participants can interact with, to further explore technological advancements for the ED diagnosis process.

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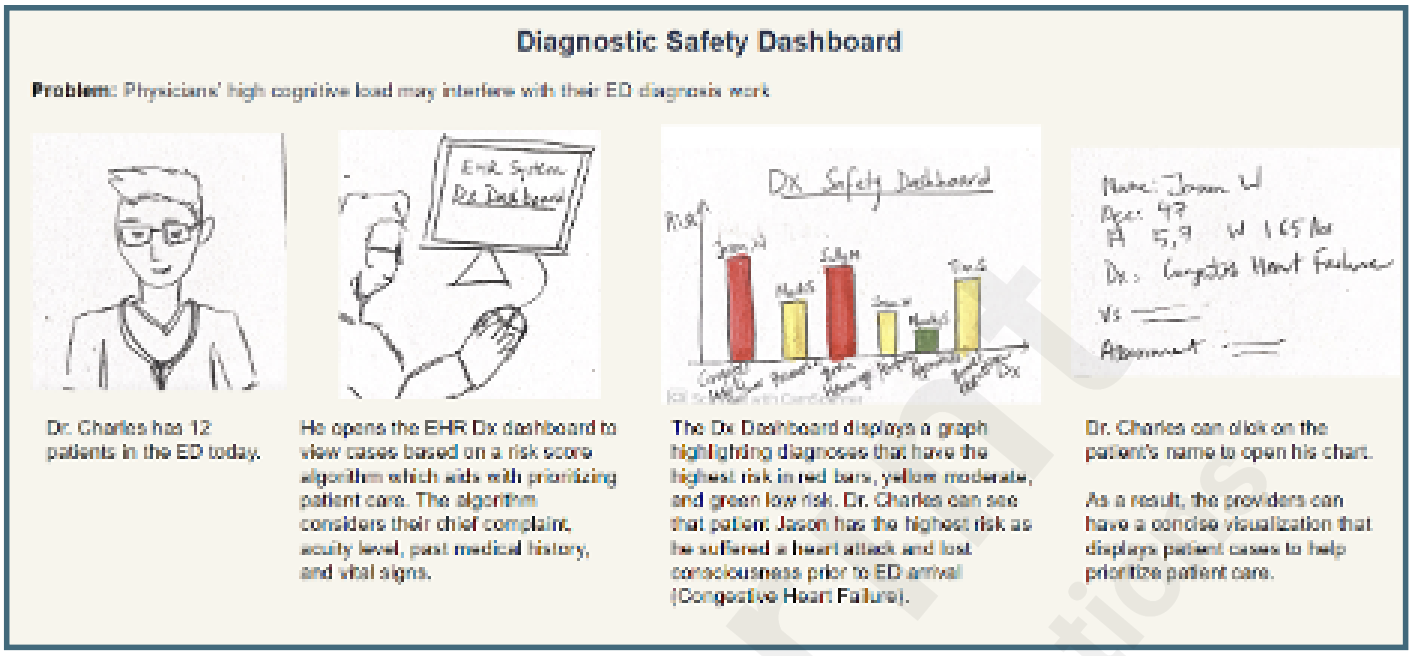
Supplementary Files

Figures

A sample storyboard illustrating how an interactive dashboard for patient risk scores can support the diagnosis process for ED providers.



Multimedia Appendixes

Sample group designs by participants from remote and in-person design sessions.
URL: http://asset.jmir.pub/assets/33e46e3cb7fa79069873311cf526d331.pdf