Alerts as Coordination Mechanisms: Implications for Designing Alerts for Multidisciplinary and Shared Decision Making

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In this study, we explore how clinical decision support features can be designed to aid teams in caring for patients during time-critical medical emergencies. We interviewed 12 clinicians with experience in leading pediatric trauma resuscitations to elicit design requirements for decision support alerts and how these alerts should be designed for teams with shared leadership. Based on the interview data, we identified three types of decision support alerts: reminders to perform tasks, alerts to changes in patient status, and suggestions for interventions. We also found that clinicians perceived alerts in this setting as coordination mechanisms and that some alert preferences were associated with leader experience levels. From these findings, we contribute three perspectives on how alerts can aid coordination and discuss implications for designing decision support alerts for shared leadership in time-critical medical processes.

CCS Concepts: • **Human-centered computing** → *Collaborative and social computing systems and tools.*

Additional Key Words and Phrases: alerts, coordination mechanisms, clinical decision support, shared leadership, teamwork, trauma resuscitation

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1 INTRODUCTION

In pediatric trauma resuscitation, a team of multidisciplinary clinical providers works together to treat a severely injured child during a critical period of time. A typical trauma team is led by a team leader (a surgical fellow or attending) and includes several other roles, each responsible for a set of tasks such as physical exam (physician examiner), airway management (anesthesiologist and respiratory therapist), and bedside care (nurses and nurse practitioners) [11]. However, anatomical, physiological, and emotional differences between adults and children often require the presence of a pediatric emergency medicine physician, who actively participates in decision making and may share other leadership tasks with the surgical fellow or attending [27, 36]. Because of their different backgrounds, the two leaders can have divergent views about appropriate approaches to

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Table 1. Interview Participants

Role	Acronym	Description	Participants
ED Physician	ED	Permanent hospital physician with extensive pediatric medicine experience	7
Surgical Fellow	SF	Physician who rotates every two years with some pediatric trauma experience	2
Surgical Resident	SR	Physician who rotates every two months and is often more familiar with adult trauma	3

patient evaluation and management. While this shared leadership strengthens the overall team's competence, it may also complicate the team's work coordination and decision-making.

Different technologies have been proposed, designed or evaluated to support emergency medical teamwork, including cognitive aids [15, 16, 23, 31], smart devices [32], electronic flowsheets [20], and wall displays [24, 30]. Some of these systems were designed for the entire team to support coordination and a shared understanding of the work process [24, 31], while the other systems were only used by the leader [16]. Even when designed for a single user, the technology still impacted team coordination and communication by influencing the user actions. We build on this prior work by exploring how alerts in these time-critical settings can function as coordination mechanisms [37], further supporting team leaders in coordinating work practices.

To understand how decision support alerts could be incorporated into existing systems, we interviewed 12 trauma resuscitation leaders. Our participants were clinicians from general surgery and emergency medicine disciplines with experience in leading trauma resuscitations. Using findings from our past research, we started the interviews by discussing four initial alerts to better understand leaders' perceptions about using these alerts as part of a decision support system like digital checklists. We then asked the leaders about other types of alerts that could support their shared work and decision making. In this paper, we focus on the collaborative aspect of alerts, providing three primary research contributions: (1) three types of decision support alerts for time-critical, team-based medical processes, (2) three perspectives on how alerts can aid work coordination, and (3) implications for designing shared alerts in these settings.

2 RELATED WORK

Prior work has explored different types of coordination mechanisms in healthcare settings, as well as the design of alerts for these settings. Below we review these areas of research.

2.1 Coordination Mechanisms in Healthcare

Coordination in clinical work is extremely complex due to the number of different groups, settings, and services involved [14]. Schmidt and Simone [37] first introduced coordination mechanisms in the CSCW literature, focusing on material artifacts and how they supported teams in coordinating and articulating work practices. Prior CSCW studies have examined various material artifacts serving as coordination mechanisms in healthcare settings, including whiteboards [6, 40], digital wall displays [5, 34], surgical videos [2], and scheduling systems [4, 8]. For example, whiteboards were found to support the relationships between different groups of users in the emergency department due to their artefactual multiplicity [6]. Bossen [7] extended Schmidt and Simone's definition of coordination mechanisms to also include immaterial mechanisms, such as organizational structures. Examples of immaterial coordination mechanisms have also been found in healthcare settings, from

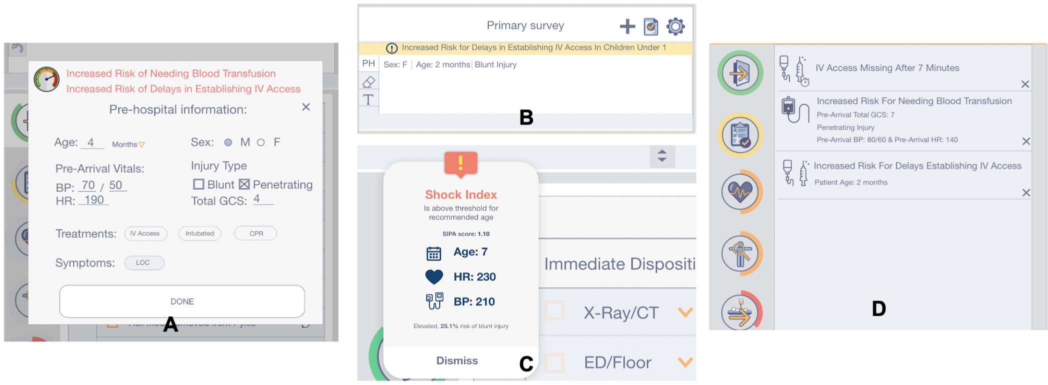

Fig. 1. Decision support alert mockups on the digital checklist shown in interviews: alerts on the pre-hospital form (A), banner alerts across the top of the checklist (B), pop-up alerts (C), and an insights screen listing alerts (D)

tacit agreements [44] to coordination by avoidance [18]. We extend this prior work by exploring how alerts can be used as coordination mechanisms in co-located teams with shared leadership.

2.2 Use of Alerts in Clinical Settings

Most medical studies evaluating the alerts focused on their effects on individual clinician actions, such as medication prescribing [28] and disease diagnosing [10]. Prior CSCW work has examined how alarms in clinical settings can impact provider awareness [17] and accountability [35]. Recent work exploring the design of alerts has focused on reducing alert fatigue, a common issue in clinical settings where users frequently ignore or override alerts. Proposed design solutions included using peripheral interactions [9], tailoring alerts to specific roles [19], and diversifying the messaging used in alerts [22]. Fewer studies have explored how alerts can be designed and used as a collaborative mechanism in healthcare settings. One exception is research examining how physicians and patients discuss alerts when collaborating to interpret medical data [1, 21, 33]. Because these alerts occurred outside the clinical setting, providers communicated with patients to understand the events leading to the alert and how the patient responded [33]. We expand on the research investigating collaborative alerts by exploring how alerts can be designed to aid coordination and communication between team members during fast-paced medical events.

3 METHODS

To elicit design requirements for decision support alerts, we conducted interviews with 12 clinicians between January and April 2021 at a level one pediatric trauma center in the northeastern United States. This study was approved by the hospital's Institutional Review Board (IRB).

3.1 Research Site and Participants

Our participants were 12 emergency department (ED) physicians, surgical fellows, and surgical residents with experience in leading trauma resuscitations at the trauma center (Table 1). This center treats about 400 patients per year using the Advanced Trauma Life Support (ATLS) protocol [38] that divides the resuscitation process into two phases—the primary survey and secondary survey. The primary survey focuses on time-critical factors involving airway, breathing, circulation, and neurological state, while the secondary survey examines the patient from head to toe to identify other injuries. A junior surgical resident performs the examination, while nurses measure the vital signs, establish intravenous catheter (IV) access, and assist with care. A respiratory therapist and anesthesiologist are responsible for managing the patient's airway.

Providers from both the ED and general surgery lead the resuscitation due to their complementary backgrounds. The ED leader is an attending, while the surgical leader is either a fellow or senior resident. A surgical attending may also be involved in more acute cases. ED physicians have a background in pediatric emergency medicine and are more experienced in medical resuscitations (children in extremis from a medical issue like asthma) than trauma resuscitations (children in extremis from a blunt or penetrating injury). Because surgical fellows and residents are primarily trained on adults, the ED physicians can assist with the pediatric nuances of the case. Both leaders work with the charge nurse to guide the team and ensure that all ATLS steps are completed. The structure of trauma resuscitation teams can vary nationally and internationally [39].

The trauma teams at our site use several different alerting technologies. The vital signs are captured on a bedside monitor and also displayed on a team-facing large wall monitor. The bedside monitor emits a beeping noise when vital signs are outside the normal ranges. During resuscitations, the surgical leader uses a digital checklist on a tablet that contains the individual tasks required in the ATLS phases. The checklist also includes a pre-hospital section for documenting patient information and treatments occurring en route to the hospital. A prepare for travel section on the checklist is used for recording future patient care plans. As the trauma team finishes tasks, the surgical leader marks them as complete on the checklist. They may also enter typed or handwritten notes on the checklist to serve as memory aids during the resuscitation process. The checklist currently has one set of alerts, which inform users that vital signs have not been documented on the checklist by pulsing the vital sign items and triggering a dropdown alert that appears at the top of the screen.

3.2 Interviews and Data Analysis

We conducted 30-minute remote semi-structured interviews with participants over the video-conferencing platform Zoom. The interviews focused on identifying alerts for a decision support system and how these alerts should be designed. We began by eliciting feedback about four potential alerts: (1) shock index (a combination of vital signs) outside of the normal range for a patient's age, (2) increased risk of needing a blood transfusion, (3) increased risk of delays in establishing IV access, and (4) IV access not established after a certain amount of time. These initial alerts emerged from our prior analyses showing that timeliness of obtaining IV access and providing blood transfusion needed improvement. We also found that the shock index score was a good indicator of the patient's clinical status. We asked participants to discuss these alerts and rank them in order of perceived importance.

Next, we presented mockups of alerts on the digital checklist interface (Figure 1). To develop the mockups, we used findings from earlier interviews and design walk-throughs with four surgical leaders. In those sessions, we asked participants about their experiences with existing alerts on the checklist and how they envisioned alerts about changes in patient status [25, 43]. We then showed a pop-up alert mockup, which informed users about abnormal shock index scores (similar to Figure 1(c)). When describing their ideas for the alerts in these earlier sessions, two participants envisioned pop-up alerts on the checklist. The other two, however, highlighted the importance of not having intrusive or distracting alerts. For the mockups presented in the current interviews with surgical leaders and ED physicians in this paper, we refined the more traditional pop-up alert and created three less intrusive options: (1) alerts appearing on top of the pre-hospital form completed before patient arrival, (2) alerts appearing on a banner at the top of the checklist, and (3) an insights screen that would list out the alerts (Figure 1). The insights screen was designed based on comments from earlier design sessions that highlighted the need to view the inputs

Table 2. Alert Categories & Suggested Alerts (# of Leaders Suggesting the Alert)

Reminders to Perform Tasks
Obtain/document vital signs (1)
Summarize case at 5 minutes (1)
Do CPR compressions and pulse checks at certain times (1)
Perform cervical spine stabilization (1)
Place electrode pads on the patient (1)
Changes in Patient Status
Changes in patient's mental status (2)
Issues with oxygenation and airway control (1)
Changes in vital signs (oxygen saturation and end-tidal carbon dioxide) after intubation (1)
Detection of extreme bleeding (1)
Suggested Interventions
Lesser-used interventions for cases with active CPR in-progress (1)
Interventions for less common injuries (1)
Interventions for penetrating injuries (1)
Decision to scan patient's head and neck (1)
Suggestion to intubate patient based on level of consciousness and vital signs (1)

informing the decisions to trigger alerts. We told users that the four mockups could be used for any of the alerts. While showing the mockups, we asked participants about alert placement preferences, how they would respond to the alerts, and which members of the team should receive them. We concluded the interviews by asking about any other types of alerts they would find helpful during the resuscitation process. After the interviews, we offered compensation to the clinicians for their participation.

The interviews were audio-recorded on Zoom with consent from participants. Two researchers reviewed and corrected the automatically-generated transcripts. Using a qualitative content analysis approach, we identified emerging themes from the transcripts in NVivo, a qualitative data analysis software. One researcher iteratively went through the transcripts to conduct open coding on suggested alerts before connecting the codes through axial coding and forming themes, i.e., alert categories. The second researcher then independently categorized the suggested alerts into the formed alert categories. The two researchers compared their categorizations of suggested alerts and discussed thought processes when performing the categorization. Inter-rater reliability was not used because it is not required in a qualitative content analysis approach. [26].

4 FINDINGS

Three themes emerged from the interview data: (1) three types of decision support alerts, (2) alert sharing between leaders to support coordination, and (3) preferences for alert types and modalities.

4.1 Types of Decision Support Alerts

Participants discussed a variety of alerts, none of which were suggested by multiple leaders. Among the many different alerts, three main categories emerged: (1) reminders to perform tasks at certain times, (2) changes in patient status, and (3) suggested interventions (Table 2).

Alerts in the first category revolved around reminders to complete resuscitation tasks by certain times. When discussing the need for an alert if vital signs were not obtained after a period of time, one participant explained how tasks could be delayed or not done, even when a team member was assigned to them:

> "I think there can be some real task distraction, in particular in complex traumas where, despite assigned roles, blood pressure is still not there, they've not figured out how to get a pulse ox probe on, because of various complications. It's a task not done." [ED#1]

When discussing their need for alerts to perform CPR tasks at specific times, a participant explained the challenges in keeping track of time while coordinating concurrent activities:

> "... I am probably more likely to notice that the heart rate is 230, but when you are addressing multiple different things, it can be easy to lose track of time." [ED#6]

In the second category, alerts focused on detecting changes in patient status, especially those in metrics that could fluctuate throughout the case and were harder to measure:

> "I wish there was a way to automatically measure and record changes in mental status. But right now, mental status, sometimes we ignore it. We do an initial assessment but then it's a pain to get to the head of the bed again... It would be great if that was automated somehow." [ED#5]

Alerts in the third category involved suggesting specific interventions based on the context of the case. Participants explained how this alert type would be especially helpful in cases where injury-specific or lesser-used interventions may be required:

> "...For most of the basic stuff, I think everybody's competent with them, but let's say you're suspecting a BCVI [blunt cerebrovascular injury] and then you're like, does this really fall under the category for me to get a CT angio?" [SR#2]

> "I think for patients that are acutely decompensating, that are active CPR in-progress, thinking through other mechanisms... thinking about those things that we don't see as commonly, sometimes we might not remember... sometimes in retrospect you're like, oh maybe we should have needle-decompressed the chest..." [ED#4]

4.2 Alert Sharing Between Leaders to Support Coordination

After reviewing the four mockups for the alerts aimed at surgical leaders, all ED leaders stated that they would also like to receive the same alerts. ED leaders explained that receiving the same alerts would contribute to a *"shared mental model"* [ED#2, ED#4, ED#5, ED#6] and that it is better to have *"two eyes on the information"* [ED#4, ED#5]. One ED leader highlighted how the ED and surgical leadership may focus on different parts of the case at different times, giving an example where the surgical leader might be coordinating a surgical procedure while the ED leader coordinates medication administration:

> "I definitely think having the surgical team and ED team having access [to same alerts] would be useful, especially if one side of the team, even though we're the same team, but if the surgical team is really focused on something and they're missing the alerts, maybe the ED team can kind of compensate and be picking them up." [ED#6]

Not sending alerts to all leaders could potentially create conflict, with one leader stating *"I think you actually may generate more confusion and potentially conflict if you're giving a set of alerts to half of your team that's making those decisions."* [ED#1]. This participant also described how alerts could be helpful in situations where the leaders have different experience levels:

> "When you have a junior surgical fellow and a 20-year on-the-job [ED] chief, I think it is not as clear that the surgical fellow is the definitive source of information and decision

> making in that room... I think actually [alerts] could help in situations like that, by getting both those people on the same page... When you have similar levels of seniority there, you may know the people involved. I think there may be more willingness to deviate from the preset protocol based on the nuances of the case, and more awareness of the resources, challenges, and constraints of the bay. It's less relevant if you have a senior fellow who's here for a year, but if you have a junior fellow who is rotating for a period of months, I think all of those things can be more challenging." [ED#1]

Another ED physician highlighted varying experience levels when discussing why all leaders should receive the same alerts, saying *"... sometimes the people leading it are less familiar with pediatrics, they're adult rotators [specialized in adult trauma], they might dismiss something that's actually important"* [ED#4].

Two ED physicians thought alerts should only be shared between the surgical leaders, ED leaders, and charge nurse. One physician described concerns that too many people receiving alerts might be *"distracting"* [ED#4], saying:

> "I feel like it's the charge nurse and the team leaders [receiving alerts], and then they can relay that information. That's how it's always been, but that doesn't mean it's right." [ED#4]

In contrast, two other ED physicians thought alerts should be shared with the entire team, saying *"if more people are aware of the same information, there's less chance of cognitive overload"* [ED#5]. A surgical leader highlighted a different reason for sharing alerts with the entire team. When discussing the alert about increased risk of delays in establishing IV access, they referenced their lack of familiarity with the room and team as a reason for having the alerts sent to everyone:

> "Whoever is going to be in charge of setting the IV line, if they get this alert, at least it's going to prompt them to know that 'okay, let me have the intraosseous close by,' or 'let me have, if I need assistance from this person who is like best at setting IV access, I'll notify the person.' Because for me, I don't know who is good at these things but they might know because the nurses have worked longer together." [SR#2]

Another surgical resident thought that urgent alerts should be sent to the entire team, while less urgent alerts could be announced to the team by the surgical leader using the digital checklist:

> "I think from my experience, we're there to help guide the things that are missing. Like, the junior residents are at the bedside doing the surveys, the emergency room attendings are looking out over everything, and the senior resident is the one with the tablet and has been making sure all the boxes are checked... and so I think that [receiving alerts] falls in line with that, of just making sure that even though we're standing off to the side or behind this black line, that we can announce it to the nurses to make sure they're working on their IV access when that alert comes up." [SR#3]

This surgical resident was concerned that some alerts would contain information already known by ED physicians with extensive pediatric experience. Because those alerts could unnecessarily burden ED physicians, they should only be shared with the surgical leader. We next describe how experience level impacted alert preferences across the two leadership groups.

4.3 Preferences for Alert Types and Modalities

We observed that experience level impacted participants' preferences around types of decision support alerts. In contrast, we did not observe the same impact of experience level on participants' preferences around modalities for the shared decision support features.

4.3.1 Preferences for Alert Types. The alert for increased risk of delays in establishing IV access highlighted the impact of experience level on alert preferences. Two of the three surgical residents said they would want to receive this alert and one senior resident even ranked it as the most important, explaining that it provides information they lack as an adult care provider:

> "I think just the gentle prompting, like this kid is going to take longer to get an IV access, out of everything we've talked about, I think that's probably the one that's the least intuitive and will be the most helpful [alert] for me." [SR#1]

In contrast, both surgical fellows and six of the seven ED physicians did not find this alert useful, saying it is *"basic to trauma"* [SF#1]. A participant worried that sending basic alerts would reduce the impact of more meaningful ones:

> "I think just telling us that it takes longer to get access in a kid under one is going to be eye-roll inducing probably for most pediatric emergency docs, that's not going to be surprising, and I worry that if you have alerts that seem obvious, it would blunt the impact of your other alerts that would be more meaningful." [ED#1]

Another ED leader confirmed this alert was not needed because they know which technicians can get IV access on any patient, saying *"as long as you know your team, you can see some of those barriers"* [ED#5.] However, rotating surgical residents lack this familiarity with the team and will have a harder time seeing those barriers.

4.3.2 Preferences for Alert Modalities. Three different alert modalities emerged from our interviews: (1) visual alerts on the digital checklist, (2) visual alerts on a wall display, and (3) audio alerts broadcast to the room. Participants did not differentiate the modality of alerts based on its type (Table 2) but described other factors that should be considered when designing alerts.

Visual Alerts on the Digital Checklist. One participant thought that the digital checklist would be a good platform for visual alerts that did not require an immediate action or for alerts triggered by information inputted on the digital checklist. Another participant explained that instead of alerts, they would prefer decision support insights built directly into the digital checklist:

> "I think the checklists are good because they keep people on track, so as you go through it, you hit certain points in the checklist, like is this a penetrating trauma, yes, is the patient's GCS less than 8, yes, consider transfusion. Things like that I think would be helpful. Or if the answers were no, it could be like a branching point, like start resuscitation with IV fluids. The person who is running the checklist could see that and incorporate that suggestion into their medical decision making... I don't think you want to create something that adds to the chaos, another system adds chaos." [ED#3]

Two ED physicians suggested that the ED leaders, surgical leaders, and charge nurse could all have copies of the digital checklist that mirrored each other, displaying the same information and alerts. However, one surgical resident was concerned about multiple leaders having tablets, explaining:

> "I think it would be a lot of people potentially staring at tablets rather than staring at what's actually going on. I think having one person with the tablet and checking off all these boxes, and the ED physician is eyes up the whole time, I would prefer that more, and then, if there was some sort of monitor that could flash these [alerts] up, then that would be a way for the physician to still see those." [SR#3]

Visual Alerts on a Wall Display. Several participants suggested that visual alerts could be displayed on a wall display located at the front of the room:

> "I wonder if one [screen] could be displaying vital signs, one could be for intubation, one or a section of one could be alerts, so that you almost have this room full of... like an air traffic control type situation." [ED#6]

Unlike the checklist, the wall display allows providers to be hands-free and perform the examination, if necessary. When shown a display on the digital checklist, one ED physician commented:

> "For me, it's another thing that takes me away from actively taking care of the patient. That's my first thought, I don't like that because I like to be really hands-on." [ED#7]

The participant later said they would prefer visual alerts on a monitor because *"... you can do multiple things... and it's also hard to have a notepad in your hand if you're taking care of the patient"* [ED#7]. Another ED physician confirmed that a display in the room with the alerts would be better for times when they have to assist with procedures and cannot hold a mobile device.

Audio Alerts Broadcast to the Room. One participant suggested that alerts about declining vital signs should be broadcast over audio to the entire team given the urgency of these alerts:

> "There's a lot going on in the trauma bay and a lot visually going on, as well as audio, but if there was something overhead that got everyone's attention to focus on the vitals, I think that would grab people's attention more than a visual cue" [SR#3]

They later explained how the urgency of the alert should affect its modality, with audio used for more urgent alerts and visuals used for less urgent alerts. Other participants expressed concerns that audio alerts would be lost in the noise of the trauma bay, with some highlighting their preference for visual alerts in locations where multiple team members could see them:

> "I think there's definitely an element of alarm fatigue, so I don't know if noise would be helpful because it's already very loud. I think a noticeable color change would be important." [ED#4]
> "It will be nice to have it in a place where everyone can see it because, again, you can't hear sometimes what people are saying, so if we see this, we automatically know what's going on." [ED#7]

5 DISCUSSION

We next discuss the implications for designing alerts that support multidisciplinary and shared decision making. Although the structure of trauma resuscitation teams can vary nationally and internationally [39], multidisciplinary teams are common across different healthcare settings, leading to better patient outcomes [12]. Our findings provide insight into how alerts can support coordination in multidisciplinary teams, and especially those with shared leadership or collaborative decision making.

5.1 Alerts as a Coordination Mechanism: Three Perspectives

Although we had started the alert design process with a single user in mind, envisioning the alerts as a tool to support individual decision-making, the interviews with clinicians showed that they also viewed alerts as a potential coordination mechanism. Our results suggest three different perspectives on how alerts could aid coordination in multidisciplinary teams. In the first perspective, offered by a surgical resident, the alerts would prompt leaders to communicate with team members to ensure tasks were being completed. In the second perspective, offered by ED leaders, the alerts would help leaders get on the same page and coordinate leadership tasks. In the third perspective, offered by a surgical resident, the alerts sent to the entire team would help individual team members better coordinate tasks with less input from the surgical leader who may be unfamiliar with team members' competencies. The last two perspectives highlight the challenges with immaterial coordination mechanisms in this setting, especially when the leadership team involves a rotating surgical resident. The familiarity between colleagues and past experiences with the setting are examples of immaterial mechanisms of interactions that can facilitate coordination in teams [7]. ED leaders discussed breakdowns in immaterial coordination mechanisms when leading with rotating residents who were unfamiliar with the setting and had less experience with the pediatric population. In these cases, the ED leaders viewed alerts as a material coordination mechanism that could help them develop a mutual understanding and shared mental model. A surgical leader discussed their lack of familiarity with team members as a temporary rotator, but thought that alerts should be sent to the entire team to help them coordinate tasks, while also reducing the amount of communicative coordination work [3] required by the surgical leader.

Although participants indicated that alerts could serve as coordination mechanisms in this setting, they also highlighted how poorly designed alerts could potentially hinder cooperation and have unintended, negative effects on the resuscitation process. Some participants worried that not sharing alerts could create conflict while others were concerned that sharing alerts between too many team members would be distracting. Participants also highlighted potential issues with distraction and confusion when discussing auditory alerts. When designing the mockups, we were focusing on how the alerts would impact the surgical leader receiving them. The interviews with participants, however, highlighted that we also need to consider how these alerts will impact the entire team, even team members who are not directly receiving the alerts. We next discuss the implications for design that arise when we consider how alerts can impact coordination.

5.2 Implications for Designing Coordinative Alerts

Three major implications for designing coordinative alerts emerged from our findings.

Determining If, How, and When Alerts Should Be Shared. Interviews with participants highlighted the complexity of deciding if, how, and when alerts should be shared between team members. As discussed above, participants had different ideas of how alerts should be shared: sent only to the surgical leader, shared between leadership, or shared between the entire team. One factor to consider when determining if alerts should be shared is the role-based preferences towards particular alerts. We found that different roles had different preferences for alerts. Surgical residents preferred an alert about delays in establishing IV access because it provided knowledge they lacked as rotating team members with less experience, while surgical fellows and ED physicians found the alert information too basic. Prior work has shown the importance of avoiding too many alerts, which can lead to alert fatigue [41]. Our participants also raised concerns that receiving obvious alerts would reduce their reactions to other, more meaningful alerts.

Another factor to consider when deciding how many team members should receive alerts is the potential for fixation errors [13]. Having too many team members focus on alerts could be at the detriment of other components of the work process. One leader in our study raised a similar point when discussing concerns that multiple leaders looking at smart devices could reduce overall awareness of the resuscitation. The urgency and importance of an alert could help determine how widely it is shared. Future work can evaluate different ways of sharing (and not sharing) alerts to better understand how they will impact dynamic teamwork. One open question is identifying which types of alerts can serve as coordination mechanisms in the resuscitation setting. For example, alerts in the *reminders to perform tasks* category may function differently than alerts in the *changes in patient status* or *suggested interventions* categories.

Designing for Accountability. The leaders in our study discussed how sharing alerts could help with accountability, suggesting that alert sharing between team leaders could reduce erroneously dismissed alerts by less experienced leaders and overall help facilitate their division of tasks (e.g., ED leaders addressing alerts when surgical leaders are focused on coordinating a surgical procedure). Prior work has found that nurses were held accountable for their choice in alarm settings by other nurses who could also view the settings [35]. Sharing alerts between team members, however, could also lead to ambiguous accountability, e.g., when determining who is responsible for fixing a problem due to shared responsibilities [29]. Designs for shared alerts should aim to reduce this ambiguity. One potential solution could be setting one team member as the owner of the alert, even if it can be viewed by multiple team members. If ownership of an alert is given to one individual, team dynamics and power imbalances will be important considerations in deciding which team member should own the alert. Future research can explore how alert ownership should be determined and designed. Next, we discuss how team dynamics influence reactions to alerts and how alerts may influence team dynamics.

Supporting Different Team Dynamics. Although our questions focused on the design of alerts, participant responses also highlighted the complexity of team dynamics during fast-paced medical events with *ad hoc* teams, frequently mentioning the differences in experience levels. When designing shared alerts to support coordination, it will be important to consider how the alerts can affect team dynamics and how team dynamics may influence reactions to the alerts. Prior work has found that mid-level clinicians thought that decision support tools amplified their voices in meetings with more experienced clinicians by providing support of their ideas [42]. For leaders who are newer to a work process and have less experience, receiving the alerts may give them more leverage to propose interventions or push for faster completion of a task. Another study observed that experience level influenced providers' deference and reactions to smart devices [32]. If team members can have different reactions to the same alert, the alert designs need to ensure that these different reactions do not create conflict. As the makeup of the leadership team and the experience levels of the other team members may impact how alerts function in a work setting, it will be important to consider the different team dynamics when designing the alerts.

6 CONCLUSIONS, STUDY LIMITATIONS, & FUTURE WORK

This study suggested several perspectives on how alerts could aid work coordination in dynamic multidisciplinary teams and elicited requirements for designing collaborative decision support alerts in fast-paced medical settings. To better understand clinicians' alert preferences and their design, we conducted interviews with 12 trauma team leaders from different disciplines and backgrounds. Three themes emerged from the interviews: (1) types of decision support alerts, (2) alert sharing between leaders to support coordination, and (3) preferences for alert types and modalities. Our study was limited by the fact that we interviewed clinicians from a single site. Resuscitation leaders at other hospitals may have different perspectives due to the organizational culture and norms, protocols, and training at their institutions. The clinicians who chose to participate in our interviews may also have had certain biases towards clinical decision support systems.

From our findings, we contribute three types of decision support alerts for time-critical medical processes, as well as an understanding of how alerts can be used as coordination mechanisms. Our findings also highlighted several challenges in designing decision support for teams with shared leadership. One challenge is mitigating different perceptions and experiences with the decision support system held by permanent and rotating team members. We also showed that participants had differing opinions on whether alerts should be sent to members of the leadership team or to the entire team. As part of our future work, we will explore these areas to further advance the design of collaborative decision support features.

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