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Learning from Non-Routine Events and Teamwork in Intensive Care Units: Challenges and Opportunities

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Abstract. Patients admitted to intensive care units (ICUs) have profound and complex illnesses, often fraught with uncertainties in diagnoses, treatments, and care decisions. Clinicians often deviate from best practices to handle ICUs' myriad complexities and uncertainties. Non-routine events (NREs), defined as any aspect of care perceived by clinicians as deviations from optimal care, are latent and frequent safety threats that, if left unchecked, can be precursors to adverse events. Proper identification and analysis of NREs that represent latent safety threats have been proposed as a feasible and more effective approach for performance improvement than traditional root cause analysis for patient safety events. However, NRE studies to date have yet to show the holistic picture of NREs in the contexts of teamwork and time-dependent tasks that are frequently associated with NREs. NREs, an upstream interventional area to understand root causes, team performance, and human-computer interaction, still needs to be expanded. This article presents concepts of NREs, and the use of real-world data (RWD) and informatics methodology to investigate NREs in contexts and discusses the opportunities and challenges to enhance NREs research in teamwork and time-dependent tasks.

Keywords. Non-routine events, intensive care units, patient safety, teamwork, tasks, electronic health records, network analysis, EHR access logs

1. Introduction

Non-routine events (NREs), defined as any aspect of care perceived by clinicians as deviations from optimal care, have a high chance of capturing minor deviations in optimal care practices and frequently occur in high-risk care environments [1]. Patients admitted to intensive care units (ICUs) have profound and complex illnesses, often fraught with uncertainties in diagnoses, treatments, and care decisions [2]. Clinicians often deviate from best practices to handle ICUs' myriad complexities and uncertainties [3,4]. Thus, NREs, a double-edged sword, may allow clinicians to neutralize potential failures; meanwhile, NREs may lead to unintended consequences or induce patient safety

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events (PSEs). Ideally, NREs should be investigated to flesh out the context of PSEs, and reveal the consequences of the deviations. However, studies to date do not report or examine NREs with their contexts, such as interactions between humans, technologies, and care settings that are associated with the causes, processes, or consequences of NREs [1]. For instance, the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) Patient Safety Event Taxonomy describes NREs from five aspects: cause, type, domain, impact, prevention, and mitigation but does not reflect interactions between humans, technologies, and care settings [5]. Studies show that teams of high performance are more resilient to display effective teamwork when NREs occur [4,6]. It has been hypothesized that the majority of NREs do not lead to adverse events because they are proactively identified, addressed, and mitigated by teams before they become or cause adverse events [3,6]. Recently, we found ICU team structures, such as the familiarity between teammates, are associated with their awareness of NREs [4]. Detecting NREs and analyzing teamwork and time-dependent tasks performed by teams to handle NREs have been a more effective and feasible approach for performance improvement than traditional root cause analysis for patient safety events. However, studies to date have not investigated NREs in the contexts of teamwork and time-dependent tasks that are frequently associated with NREs [1-6]. Therefore, NREs serving as substantial evidence for an upstream interventional area to analyze PSEs have not been well explored. This article starts with an example to show NREs in the context of time-dependent tasks and teamwork, followed by an introduction to the NRE concept, context, and consequence (3Cs). Next, the article discusses opportunities for using electronic health records (EHRs) and network analysis to learn the 3Cs of NREs. Finally, the article depicts challenges in the learning of NREs.

2. Methods

An example of NREs [7]. A medication error in critical care introduced here illustrates the interplay of humans, technologies, and settings in generating NREs. An adult patient admitted to the ICU was found confused with severe hyponatremia (sodium 109mEq/L, normal range 135mEq/l). A nephrology consultant asked an intensivist to immediately administer hypertonic saline (3% sodium) to increase the sodium level and to recheck the sodium level in one hour. Note that the nephrologist did not specify how much hypertonic saline should be administered. When the nephrologist came to the ICU two hours later, the patient's confusion had not improved, and the patient's sodium had risen to 130 mEq/dL, a rapid increase that put the patient at risk of severe neurologic complications. The nephrologist noticed that a 500 mL bag of hypertonic saline had nearly finished infusing. The infusion was stopped immediately, and the patient was administered medications to mitigate the effect of the rapid sodium correction. Fortunately, the patient's sodium stabilized, and his mental status gradually improved. Further investigation revealed that the intensivist had intended to order the administration of 50 mL of 3% saline. However, the default intravenous fluid order in the computerized order entry system was for a 500 mL infusion. A separate, customizable order was available but not easily accessible. In a rush, the intensivist ordered the 500 mL infusion and added a free-text comment to "infuse 50 mL then recheck sodium." Unfortunately, the free-text comment was missed by the pharmacist and ICU nurse, resulting in the patient receiving a much larger infusion at a faster rate than intended. The NRE revealed miscommunication mediated by Health IT between the two clinical

decision makers and among those healthcare professionals, resulting in partial, incomplete, and inaccurate information conveyed in the ICU workflow and poorly designed Health IT, lack of high-performing teamwork, and deviations/workaround under time pressure that can be considered as the holes aligned to permit penetration of an error. Thus, NREs play an essential upstream role in signaling adverse events when healthcare professionals perform time-dependent tasks in minimal intervals to handle the myriad complexities and uncertainties. A recent study shows that NREs in neonates undergoing gastrostomy tube placement found over 80% of surgical cases had an NRE reported by involved clinicians, and 19% had adverse events represented by the national surgical quality improvement program – pediatrics terms (NSQIP-P) [3]. Therefore, it is urgent to understand NREs in the context of healthcare settings, such as ICUs, where effective communication among all care team members is critical for understanding the timely start and discontinuation of therapy to achieve optimal clinical outcomes.

NRE concept, context, and consequence (3Cs). NREs are latent and frequent safety threats that, when left unchecked, can result in unintended consequences, including unsafe conditions or near misses. Understanding NRE concepts and investigating their context and consequence is deemed upstream research in contrast to PSE studies. The concept described here is that of an NRE in the context of a patient with hyponatremia in the ICU setting. The NRE occurred when the patient was administered hypertonic saline in an amount greater than what was prescribed due to a workaround in the EHRs order entry system.

- *Concept:* An NRE is a deviation from the expected course of treatment that can result in unsafe conditions, near misses, or incidents.
- *Context:* The context of the clinical setting is vital to understand the complex interplay between humans, technologies, and the setting, which can affect patient outcomes. In this case, the EHRs order entry system had a workaround that was identified, despite a separate and customizable order entry being available in the system. The ICU setting is a typical interplay of humans, technologies, and setting where the patient's vitals, clinician tasks, care team's preparedness, composition, and dynamics are key factors in the interactions between human-computer and human-human. A workaround in the EHRs order entry was identified in spite of a separate and customizable order entry being offered in the system. The context is essential to complement a holistic view of the NRE.
- *Consequence:* The consequence of the NRE is that the patient's treatment was affected, but timely intervention prevented any harm or minimal impact on the patient. Although the miscommunication affected the patient's treatment, the NRE consequence was not harmful or had minimal impact on the patient because of timely intervention.

It is crucial to understand and learn from NREs to improve the safety and quality of care provided to patients and to identify and address any underlying system or process issues that may contribute to the occurrence of such events. The case indicates that patient safety research focusing on the upstream of event progress of NREs could provide an excellent opportunity to mitigate potential risks.

3. Results

Real World Data (RWD) to learn time-dependent tasks in the NRE context. Studies on NREs heavily rely on human observers to capture the 3Cs of NREs. Although observational studies can document various types of NREs, the studies are labor-intensive, time-consuming, and challenging to capture the fine-grained context of NREs, such as interactions between human-human and human-technology when NREs occur [1,3]. Over the past decade, EHRs have been widely deployed across the United States to advance health information interoperability and accessibility [8]. RWD stored in EHRs streamlines time-intensive processes and contributes to efficient clinical decision-making. As such, EHR utilization has been indivisibly integrated into care routines. EHR access logs capturing the human-computer interactions in EHRs are one of the big data sources for investigating EHR tasks and corresponding utilization workflows to complete the tasks. Our recent publication demonstrates the effectiveness of using EHR access logs in learning complex and time-dependent tasks performed by healthcare professionals [9,10]. Building connections between NREs and EHRs would enable the investigation of NRE contexts, for instance, how EHRs support the completion of time-dependent tasks.

Network analysis to learn team composition, relationship, and performance. Studies show that teams of high performance are more resilient to display effective teamwork when NREs occur [4,6,11]. It has been hypothesized that the majority of NREs do not lead to adverse events because they are proactively identified, addressed, and mitigated by teams before they become or cause adverse events. Investigating how teams behave or perform when NREs occur is expected to facilitate the development of team assembling or training strategies to be suited to the context of NREs and consequences. Previous studies suggest that team structures, such as the familiarity between teammates, are associated with their awareness of NREs [4]. Network analysis (NA), the most commonly used model for analyzing complex relationships between healthcare professionals, can provide a comprehensive picture of a team's topological structure, allowing us to scale from the individual healthcare professional level to the team level. NA in healthcare has been growing as a science subject for decades and yielded comprehensive network metrics to measure team composition, familiarity between teammates, healthcare professionals who work with others to coordinate patient care, critical healthcare professionals who lead teams, and the heterogeneity of a team in terms of professionals' expertise and experience [12].

4. Discussion

To investigate NREs in context, it has to start from one typical ICU setting with a defined duration to collect and identify sufficient NRE cases. Inevitably, the generalizability may not be warranted in other settings, even if the setting may exhibit similarity yet the team structures and strategies vary. Moreover, patients in ICU present a diversity of critical illnesses that need the care team to respond in a timely manner. Therefore, there should be sufficient cases to ensure the success of learning NREs contexts, including patients' health status and time-dependent tasks. Identifying healthcare professionals involved in an NRE from the NRE-involved patient's EHRs can be a potential risk because some healthcare professionals may not perform actions to the EHRs of the patient during the care. Combining EHRs with other advanced technologies, such as computer vision (CV) technologies, will enhance the learning of NREs. CV analyzing audiovisual data in an

automated way can capture human-human or human-technology interactions that are not captured by EHRs.

5. Conclusions

NREs are upstream events in the context of patient safety, which are critical and impactful to quality and safety but, unfortunately, understudied. Available data supporting NRE research present challenges and opportunities in revealing the context of human-human and human-computer interactions. Understanding the ICU context regarding individuals, team interactions, and technology is expected to promote the application of teamwork analysis and create actionable criteria to enhance quality and safety.

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