Characterizing the Structure and Content of Nurse Handoffs: A Sequential Conversational Analysis Approach

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Abstract

Effective communication during nurse handoffs is instrumental in ensuring safe and quality patient care. Much of the prior research on nurse handoffs has utilized retrospective methods such as interviews, surveys and questionnaires. While extremely useful, an in-depth understanding of the structure and content of conversations, and the inherent relationships within the content is paramount to designing effective nurse handoff interventions. In this paper, we present a methodological framework—*Sequential Conversational Analysis* (SCA) —a mixed-method approach that integrates qualitative conversational analysis with quantitative sequential pattern analysis. We describe the SCA approach and provide a detailed example as a proof of concept of its use for the analysis of nurse handoff communication in a medical intensive care unit. This novel approach allows us to characterize the conversational *structure*, clinical *content*, *disruptions* in the conversation, and the inherently *phasic* nature of nurse handoff communication. The characterization of communication patterns highlights the relationships underlying the verbal content of nurse handoffs with specific emphasis on: the interactive nature of conversation, relevance of role-based (incoming, outgoing) communication requirements, clinical content focus on critical patient-related events, and discussion of pending patient management tasks. We also discuss the applicability of the SCA approach as method for providing in-depth understanding of the dynamics of communication in other settings and domains.

Keywords: Conversational Analysis, Sequential Analysis, Care Transitions, Communication, Communication Errors, Nurse Handoffs, Intensive Care

1   Introduction

Patient handoffs involve the transfer of information, responsibility, and control between care providers and are viewed as an *ubiquitous, clinical* and *organizational* activity [1]: *ubiquitous* as they occur across various groups of clinicians; *clinical* as they serve as a forum for sharing patient-related information; and *organizational*, as they occur at all levels of a hospital. Nurse handoffs (also referred to as "shift reports") are the most frequent [2], averaging approximately 2 million per year in a mid-size hospital [3, 4]. Failures during handoffs contribute to nearly 35% of sentinel events and medical errors [5, 6]. These failures arise from limited structure during communication [7], multiple communication approaches [8], time constraints [9, 10], interruptions and distractions [11, 12], lack of training [13], and communication bottlenecks [14-18]. These failures have been associated with incorrect or delayed diagnosis and treatment, prolonged morbidity, increased patient length of stay, clinician and patient dissatisfaction, and increased costs [19-21].

To promote safer handoffs, The Joint Commission (TJC) spearheaded efforts [22-24] to standardize communication activity [15, 25], leading to the development and implementation of new or re-designed handoff strategies and processes [26, 27]. These efforts have also led to standardization initiatives and the development of handoff tools based on templates, spreadsheets, checklists and mnemonics [28, 29]. While these solutions have been widely implemented, there is still a lack of consistency in their adoption and use [30]. It has generally been acknowledged that the standardization efforts should rely on understanding the content and structure of handoff communication [31]. Although TJC has launched such efforts to *standardize the content of communication*, there is little agreement, as to "what" needs to be standardized and "how to" standardize—both in terms of clinical content, and its structure [21].

Developing an informed understanding of the content and structure of handoff communication can have implications not only for minimizing communication errors in nursing practice, but also for developing evidence-based guidelines for handoff training, and the design of nurse handoff interventions. However, much of the prior research on handoffs, with some notable exceptions (e.g., [32]), are "descriptive" relying on retrospective evaluations, rather than developing a "deeper understanding of what they [handoffs] are, what needs they serve, and what actually happens in them" [33]. Part of the reason for such evaluations can be attributed to the lack of

methodological approaches for: (a) tracing the evolution of handoff conversations, (b) investigating the inherent relationships within these conversations, and (c) identifying causes of disruptions during conversations. In this paper, we introduce a methodological framework, *Sequential Conversational Analysis* (SCA) that relies on a mixed-method approach that integrates a qualitative conversational analysis with a quantitative sequential pattern analysis for evaluating interactions during handoffs.

2   Methodological Approaches for Studying Handoff Communication

In this section, we describe prior research on nurse handoff communication, focusing on the evaluation techniques that have been previously used. Next, we describe the SCA approach and its applicability for analyzing communication.

2.1   Background: Communication during Nurse Handoffs

Nurse shift report serves as an interactive forum for transfer of information regarding the patient, family and other contextual issues [34, 35]. With the sheer volume and frequency of shift changes, ensuring safe, effective and efficient handoffs is challenging, but critical for maintaining care continuity across shifts [36]. Besides supporting patient care, researchers have emphasized that nurse handoffs provides social and psychological support for achieving nursing staff cohesiveness, professionalism, socialization and learning. Given the primary function of information transfer, nurse handoffs have been characterized as a "ritual" [37, 38].

Studies of nurse handoffs have been conducted using several methods including interviews, case narrative reports, questionnaires and surveys (e.g., [39, 40]). Using these methods, most research studies have highlighted perceived barriers for nurse handoffs including general communication problems, human factors issues, social and hierarchical problems, time and environmental constraints [22, 41]. Evaluation studies of handoff tools using these methods have shown improvements in nurses' perceptions of increased usefulness and efficiency, improved standardization of communication, improved information sharing skills, and most importantly, nurses' confidence and satisfaction with communication [22, 42]. For example, Nelson et al. [42] conducted a *survey-based* study to investigate nurse satisfaction on the use of a handoff tool. They found that the handoff tool improved perceived usefulness and efficiency of the overall nurse workflow by reducing time spent on preparatory handoff communication activities. Similarly, Jukkala et al. [43] used surveys to report on nurse perceptions regarding a handoff tool

based on the body-systems format. They found that standardization of content using the tool enhanced perceptions of communication effectiveness. Other survey-based studies (e.g., see [44]) showed perceived improvements in standardized communication and workflow efficiency. Baldwin and McGinnis [22], using a questionnaire-based study, reported that 86% of their participants preferred the problem-based sign-out tool as it reduced chances of overtime, increased direct patient care time, and improved communication of patient data. *Interviews* have also been used for evaluating the nurse perceptions of the quality of handoff communication. For example, Roberts et al. [45] used interviews to illustrate the effectiveness of an SBAR (Situation, Background, Assessment and Recommendation) tool for handoffs. Interviews with nurses highlighted the importance of structured communication tools in facilitating collection and transfer of critical safety data that otherwise may have been lost.

As highlighted above, much of the prior research on nurse handoff communication, both with and without tools, has relied primarily on obtaining perspectives of the participant nurses using user-based surveys, questionnaires, and interviews [26, 33]. While these studies are useful in characterizing the nature and perception of handoff quality, and care transition activities of nurses (e.g., [46]), they provide limited understanding of the dynamics of handoff conversations, especially with regards to the structure and content of communication.

Exceptions are studies by McCloughen et al. [2] and Carroll et al. [32] that have used complementary methods to understand the actual content of nurse communication. McCloughen et al. [2] used content analysis of nurse communication to explore the purpose, intent, practice, processes, and quality of handoffs in an inpatient mental health setting. They found that handoffs were retrospective, problem-focused, and inconsistent as they lacked structure and context. Similarly, Carroll et al. [32] investigated the nature of communication exchanges between nurses at shift change. Based on a multi-method study using audio recording of handoffs, interviews, surveys and review of patient records, they identified significant variations in the nature of communication based on role (incoming vs. outgoing nurses), and years of clinical experience. They also found that incoming nurses wanted an interactive conversation about the patient, while outgoing nurses wanted to present information without being interrupted. Similarly, experienced nurses provided shorter reports than less experienced ones, which led to significant number of follow-up questions, especially, by less experienced incoming nurses. While these studies highlight the importance of evaluating the content of clinical conversations, an in-depth

understanding of the communication process and conversational strategies that are instrumental in designing appropriate handoff interventions is limited [2, 22, 47, 48].

In the following section, we present a new methodological approach, Sequential Conversational Analysis, to evaluate the content, structure and nature of roles and relationships within handoff conversations. Such an approach also helps in examining the understated functions of handoffs such as social interactions, shared understanding, and distributed cognition [26, 31, 33, 49, 50].

2.2   *Sequential Conversational Analysis*

SCA is an exploratory mixed-method approach that combines in-depth qualitative analysis (using conversational analysis) with statistical temporal pattern analysis (using sequential analysis). SCA is based on the exploratory data analysis paradigm that relies on summarizing data through an open-ended approach, and does not rely on a priori hypotheses or statistical models [51-53]. Three inherent attributes of communication make SCA a viable and effective approach to study handoffs: (a) structural and semantic properties of communication; (b) inherent temporal properties of interactive communication; and finally, (c) breakdowns during the conversations, and its relationships with the structural and temporal characteristics.

SCA uses a combination of conversational and sequential analysis techniques. Conversational analysis (CA) is a methodological approach for studying verbal interactions, and relies on procedural analysis of audio or video-recorded communication [54, 55]. It involves an in-depth analysis of how participants organize their conversations including the content of their conversations, turn-taking behaviors, collaborative development of actions and plans, and problem solving. CA is a form of discourse analysis, but utilizes a more holistic perspective, relying on both the verbal and contextual aspects during interactions [56]. CA has been used in a variety of contexts to evaluate physician-patient communication [57], the effect of decision-making technology on primary care consultation [58], team situation awareness, and communication in operating rooms [59]. Sequential analysis approaches are used to identify temporal patterns of human interactions [60-62]. Given the temporal and interactive style of handoff conversations (i.e., that involves presenting and receiving of information), sequential analysis approaches provide an effective basis for identifying repetitive patterns within temporal

data. For example, Kannampallil et al. [51] used this approach to compare the strategies based on identification of information seeking patterns among nurse practitioners and residents.

Applying the SCA approach involves three steps: (a) data collection and processing of audio or video recorded verbal communication data, (b) conversational coding and analysis, and (c) communication event transformations and sequential analysis. Data collection and processing involves the collection and transcription of verbal data and its segmentation into functional units of conversation. Functional units are the psychological analogs of a single unit of experience and are syntactically coherent units that correspond to speech acts such as statements or commands [63, 64]. A number of coding schemes can then be applied to categorize the functional units. For example, conversations can be coded based on their clinical content, or conversational strategies, or disruptions (breakdowns). The coding of the functional units provides a mechanism to categorize the conversational content, at the level of the smallest coherent conversational level (i.e., functional units).

Sequential analysis can then be used to characterize the underlying patterns of the conversations within each of the considered dimensions (e.g., structure or clinical content). For sequential analysis, coded categories are converted into event streams (i.e., a sequences of coded categories). For example, consider the coding of a handoff conversation on the clinical content dimension was along 5 variables: *cc1* through *cc5*. Each functional unit will be assigned a category resulting in the entire conversation having a clinical content categorization. For example, an event stream for this conversation could be cc1, cc3, cc2, cc5, cc1…cc3. For statistical analysis purposes, event streams need to be converted into antecedent-consequent event transition matrices. These transition matrices are the basis for conducting categorical analysis to identify temporal relationships. Several techniques can be applied to the antecedent-consequent matrix to characterize sequential relationships: sequential pattern analysis [51, 62], lag sequential analysis [65], log-linear modeling [66], and information theoretic approaches [67]. The right half of Figure 1 shows the sequential analysis component—from creating events to developing transition matrices and various sequential pattern analyses. The left half of Figure 1 illustrates the organization and processing of data followed by conversational analysis. Below, we present a case study on the use of the SCA approach to identify the key characteristics of nurse communication: to identify *transitions* in communication (i.e., turn taking behavior

between incoming and outgoing nurses), *structure* of communication (i.e., conversational strategies), the *clinical content* exchanged and *disruptions* during handoffs.

Data Collection & Processing

Record verbal conversations [Audio/Video]

Transcribe and segment conversations into functional units

Conversational Analysis

Code functional units (e.g., communication events, disruptions, clinical content)

Qualitative summary of conversational patterns

Sequential Analysis

Event 1
Event 2
Event 3
....

Event 89
Event 90
....
Event n

$$\begin{pmatrix} P_{00} & P_{01} & P_{02} & P_{03} \\ P_{10} & P_{11} & P_{12} & P_{13} \\ P_{20} & P_{21} & P_{22} & P_{23} \\ P_{30} & P_{31} & P_{32} & P_{33} \end{pmatrix}$$

Converting coded functional units (communication events, clinical content, disruptions) into temporal event streams

Statistical or descriptive analysis of event streams (Chi-square and Lag Sequential Analysis)
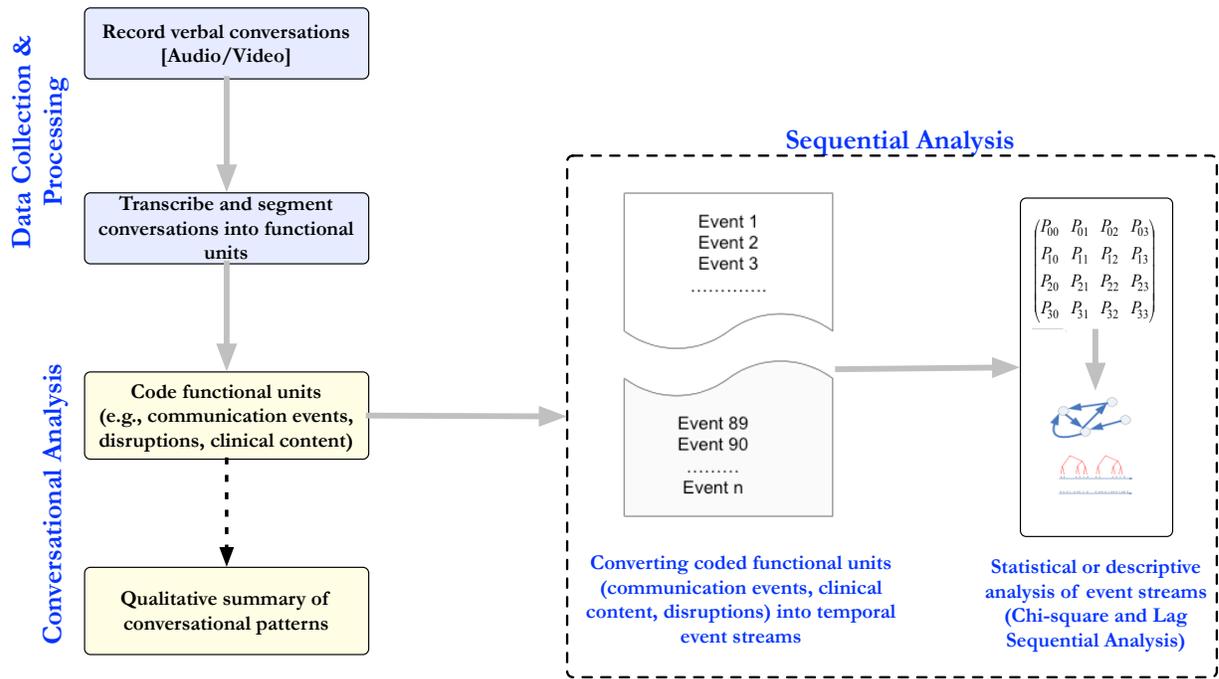
Figure 1. Sequential Conversational Analysis framework highlighting the three stages – data collection, coding using the conversational analysis and the temporal sequential analysis.

3   Evaluation of Nurse Handoff Communication: A Case Study

In the rest of this paper, we describe a case study on the use of the SCA approach on evaluating and analyzing nurse handoff communication. Our focus with the case study is two-fold: first, to describe how the SCA approach can be used to analyze interactive communication data; and second, to highlight the insights that can be drawn regarding the nuances of handoff communication, specifically related to the structure and content of interactive nurse handoff communication using the SCA approach. This study was part of a larger, longitudinal effort on investigating the nature of care transitions in critical care settings.

In the rest of this section, we describe the participants, setting, data collection, and the use of the SCA approach for analyzing nurse handoff communication. The Institutional Review Board approved the study and written consents were obtained from all study participants.

3.1   Study Setting and Participants

The study was conducted at a 16-bed medical intensive care unit (MICU) at an academic medical center in Texas. Nurses worked 12-hour shifts and were responsible for two patients during their shift. Handoffs occurred twice a day (at 6AM and 6PM) at shift changes. There were several factors that influenced nurse assignments: patient acuity (e.g., new nurses were not assigned very sick patients), prior knowledge of a patient, (e.g., if a nurse had provided care for a patient previously, then s/he would likely be assigned the same patient); and spatial considerations (e.g., a nurse was likely to have two co-located patients). Other considerations for nurse assignment included patient requests and cultural factors (e.g., language). The average patient length of stay in the MICU was 4 days.

Table 1. Distribution of participants across the 15 data collection sessions; Nurses are given unique identifiers from N1 through N16 (16 participants). Table shows the outgoing nurse and incoming nurses for each session, their shift, repetition of participants and the patients (P1 through P7) that were discussed.

Handoff No.	Outgoing Nurse	Incoming Nurse	Time of Handoff [*Handoff*]	Patient No.
1.	N1	N2	6:00 PM [*Evening*]	P1
2.	N2	N3	6:00 AM [Morning]	P1
3.	N4	N2	6:00 PM [*Evening*]	P1
4.	N5	N6	6:00 PM [*Evening*]	P1
5.	N6	N5	6:00 AM [Morning]	P1
6.	N7	N8	6:00 AM [Morning]	P2
7.	N9	N10	6:00 PM [*Evening*]	P3
8.	N11	N9	6:00 AM [Morning]	P3
9.	N9	N11	6:00 AM [Morning]	P3
10.	N12	N13	6:00 PM [*Evening*]	P4
11.	N13	N10	6:00 AM [Morning]	P5
12.	N13	N14	6:00 AM [Morning]	P4
13.	N2	N15	6:00 AM [Morning]	P6
14.	N15	N2	6:00 PM [*Evening*]	P6
15.	N5	N16	6:00 PM [*Evening*]	P7

Sixteen (*N*=16) MICU nurses participated in the study over a 2-month period on 15 handoffs (See Table 1 for the list of nurses, coded as N1–N16, the 15 handoff sessions, and the 7 patients, P1 – P7). All participants were critical care nurses; some of the participants had CCRN certification (Certification for Adult, Pediatric and Neonatal Critical Care Nurses).

3.2   Nurse Handoff Tool

All participants used a paper-based body systems-based handoff tool to document patient care information for handoffs. Clinical content included patient administrative data, code status, clinician orders, problem list, assessment and plan, medications and treatments, lines and invasive devices, and lab results. The content was organized into a head-to-toe body system-based (or organ) information format that included neurological, pulmonary, cardiovascular, gastrointestinal, and genitourinary systems.
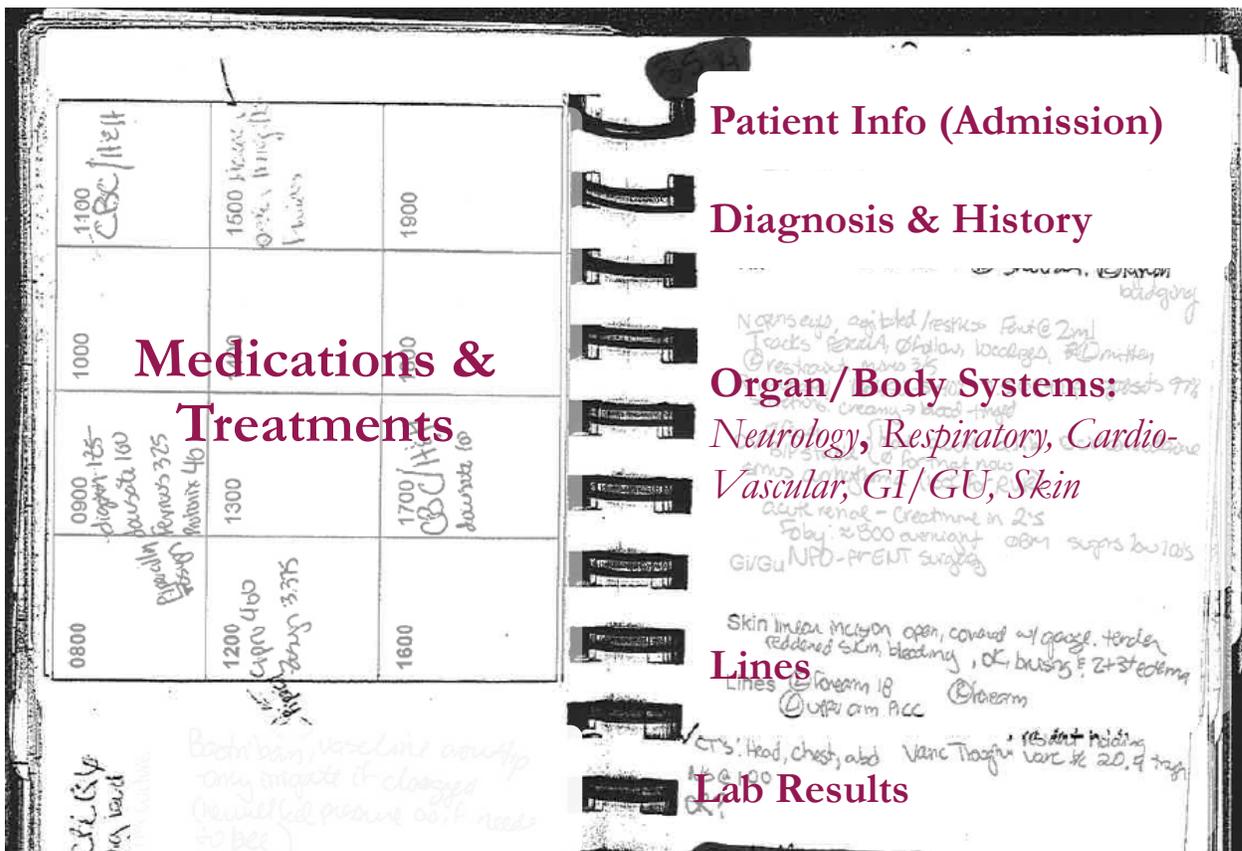
Figure 2. Structural organization of the body-system based handoff tool (with the different areas highlighted) used in the MICU.

The clinical information within each body system was organized in a narrative format. For example, within the neurology system, nurses documented the problems, assessments, results, and plans related to the nervous system (and patient's psychological behaviors). In addition, the tool included a section for incorporating a brief history of the patient, primary diagnosis, allergies, code status, and other care related information such as labs, radiology reports and medication orders and treatments (each of which was organized in a temporal fashion). Prior

evidence suggests that nurses are trained using the body systems format (as part of their nursing curriculum), and hence such a format is an effective mechanism for presenting clinical information [68]. The handoff tool used by nurses is shown in Figure 2.

3.3   Nurse Handoff Communication

During nurse handoff sessions, the outgoing nurse verbalized patient information to the incoming nurse in a narrative style, while referring to their personalized hand-written notes. Incoming nurses noted down relevant details on their own body-system based tool. The incoming nurse's notes were updated during their shift with new and relevant patient information, and were used for their own ensuing handoff session at the end of their shift. The majority of information exchanged during handoff occurred outside the patient's room at the nurse's workstation. An example snippet of the transcribed handoff communication is shown in Figure 3.

Outgoing Nurse: He is a   ....*deleted* [*age*]...   , CHF probably; hyperthyroid. He presented with pneumonia, they diagnosed it as COPD, I mean CHF exacerbation. So they gave him lasix, no fluid, dropped his BP and then under main propofol and sent him to us...

Incoming Nurse: Is this the ER? or...

Outgoing Nurse: No, this is   ....*deleted* [*location*]

Incoming Nurse: Oh, ...*deleted* [*location*]   , OK.

Outgoing Nurse: Neuro-wise, he is very pleasant. He is awake and is thankful for everything you do.

Incoming Nurse: Cool

Outgoing Nurse: Respiratory-wise, he is on a couple of liters of Oxygen on 99-100%. However, tonight if he has episodes of de-sating, you probably need a bi-pap for sleep apnea. He has not been diagnosed with it. But he is like 400+. He is clear for me. CV-wise he has regular heart rate at 80s, 90s. He is on amiodarone at home. So I guess he is probably at it for hypertension. His blood pressure is like 90 over 60 levo. I have give 3 liters of fluid and i am only giving him 1 every hour.

Incoming Nurse: you said 3?

Outgoing Nurse: I said 3, but I have given him 1 per hour and then kind of re-evaluating and let him do at 9,9,9 rather than like pressure bagging him in fast.

Incoming Nurse: Right, right, right

Figure 3. An example snippet from our data showing the handoff communication

3.4   Data Collection

Audio recording of communication during shift reports, general observations of nurse workflows, and semi-structured nurse interviews were the primary sources of data for this study.

3.4.1 Audio recording of Shift Reports

Fifteen nurse handoffs were audio-recorded ($N_{morning}$=8; $N_{evening}$=7). We also took field notes regarding the nurses' non-verbal behaviors and actions (e.g., accessing the patient chart or monitor, level of eye-contact) during handoffs. Given that the field notes were hand-written, the granularity of these notes was not detailed enough to systematically evaluate specific non-verbal interactions. However, these notes provided socio-contextual details around the observed handoffs. The average length of a handoff was 516s [SD=161s].

3.4.2 Observations and Interviews

In order to contextualize handoffs within nurse activities and workflow, we (first author and a graduate student in biomedical informatics) conducted over 20 hours of ethnographic observations. These observations were on days when shift reports were recorded. The purpose was to understand nurses' tasks and activities, both before and after handoffs. Three formal (i.e., scheduled, semi-structured) and four informal (i.e., during observations after handoffs) interviews were conducted with participating nurses. The purpose of these semi-structured, formal interviews was to obtain an understanding of the nurses' perceptions on the handoff process including pre-handoff preparatory activities, post-handoff management activities, information needs during handoffs, commonly encountered challenges, and workaround strategies that were used to alleviate bottlenecks in workflow. Nurses were asked to describe these within the context of their incoming and outgoing handoff roles. The interview guide that was used can be found in the supplementary material (see Appendix 1). These interviews were scheduled and conducted in the nurse's lounges or break rooms and lasted an average of approximately 15 minutes.

Informal interviews were conducted prior to, or after handoffs to gather insights regarding work activities around handoffs or clarify specific observed instances. These instances often involved clarifications regarding why certain tasks were performed in a particular way (e.g., use of electronic tools during handoffs) or questions regarding unique emergencies (e.g., a code event), and its impact on care continuity.

3.5 Data Analysis

The coding and analysis process involved bi-weekly meetings for peer de-briefing. We used the grounded theory approach for analyzing open-ended field notes and interviews [69]. Audio-

recorded handoff communication data was analyzed using the SCA approach. Each of these is described in further detail.

3.5.1 Analysis of Observations and Interviews

We used grounded theory based open coding approach to analyze various aspects of nurse handoff workflow activities. Examples of open codes included nurses' information and communication needs, interruptions, tasks (before and after handoffs), chart use, and interactions with members of the care team and the patient's family. Next, we performed axial coding that involved the identification of relationships between previously identified open codes to generate a core set of categories. A prototypical example of an axial code was nurse's information documentation tasks on patient's EHR (Electronic Health Record) before completing the shift. Once the axial coding was completed, we reviewed our field notes to selectively code any data that related to the core categories to generate a theory or a collection of explanations that described nurse workflow, and the use of the system-based tool to support information exchange during handoffs.

3.5.2 Analysis of Audio Recorded Handoffs

Verbal communication from each nurse handoff session was transcribed verbatim for analysis. Data analysis involved two phases: a qualitative conversational analysis phase, where transcripts were segmented, and coded along multiple dimensions of communication; and a quantitative sequential analysis phase, where temporal sequential pattern analysis was performed to identify potential patterns in communication across nurse handoffs. The various steps in each of these phases are described in detail below.

3.5.2.1 Conversational Analysis

Qualitative analysis followed a conversational analysis approach [70, 71]. This approach has been previously used to explore the purpose, intent, practice, processes, and quality of nurse handoff [2], and the content analysis demonstrated that these handoffs were retrospective, problem-focused and inconsistent as they lacked structure and context. Other studies have utilized similar discourse and content analysis approaches within the context of handoffs [72, 73].

Segmentation of Content: Verbal content was segmented into functional units of conversation, which are defined as the psychological analogs of a single unit of experience [64, 72]. While these were usually syntactically coherent units corresponding to speech acts such as statements or commands, single words could also be units if they functioned as separate speech acts (e.g., "okay"). For each functional unit, we recorded the speaker (i.e., *A*: outgoing; and *B*: incoming), and the position of the spoken content in the transcript (i.e., line number). Table 2 provides an example of the segmentation of the content. To evaluate the reliability of the segmentation process, two coders (JA, CJB) separately coded functional units in two transcripts. The two coders then compared their coding of the functional units. Disagreements regarding the classification of functional units were resolved through discussion and a mutually agreed segmentation was derived. The ratio of changes that were made to the segmentation was used as a measure of reliability. The two coders had 94% agreement.

Table 2. Segmentation of functional units in nursing handoff communication.

Speaker	Description	Example (from data)
A (*Outgoing Nurse*)	A meaningful piece of information from the outgoing nurse	A: "I was drawing labs sometime, I drew labs and sent them - they wanted to do magnesium so the bag is hanging down."
B (*Incoming Nurse*)	A meaningful piece of information from the incoming nurse	B: "So did we ever get the sputum?"

Segmented transcripts were further coded along three dimensions: structure, clinical content and disruptions in communication. The *structure of communication* dimension was used to identify the conversational strategies that were used during collaborative interactions for transferring patient related information, and establishing common ground. In other words, this dimension can be used to characterize the nature of collaboration during communicative interactions. The *content of communication* dimension was for identifying the nature of clinical content during the conversations. The *disruptions* in communication were used as a surrogate measure for representing the communication gaps during handoffs.

Structure of Communication: During collaborative interactions, conversations coordinate both content and processes—whereby speakers develop a shared understanding of the exchanged information. The process of creating such a shared understanding is the basis for effective collaborative interaction [74-76]. Capturing the strategies used to maintain the continuity of conversations provides insights into the underlying structure of communication. We used a

modified version of the structured communication coding framework by Clark and Schaefer [77] to categorize the types of conversational moves during handoffs (see Table 3).

Table 3. Structure of communication during collaborative interaction in nurse handoffs (modified from [77]).

Conversational Moves during Collaborative Interaction	Definition	Example (from data)
Present	Presenting patient information	"Neuro-wise, she's been following commands for me"
Seek	Requesting additional information	"They didn't perform the drip?"
Propose	Provide recommendation for care delivery (e.g., plan)	"and ...after that you can turn it off, okay?"
Critique	Rejecting a some part presented information	A: "and she's on Levo at [PAUSE]." B: "I think it's off."
Revise	Revise the information based on the critique	"Oh, okay. I had it at 5."
Accept	Accept presented information	"Yeah, I'll keep it on."
Meta-Cognition	Information about regarding reasoning or thoughts	"If his cardiac output starts to drop, then you will say his heart is acting up."

The first author (JA) coded all transcripts for conversational strategies; the third author (CJB) coded one representative transcript (11.32% of total functional units) with high inter-rater agreement (*Cohen's Kappa*=0.89, 96.18% agreement).

Clinical Content of Communication: By analyzing each functional unit, we categorized the clinical information exchanged during handoffs. For this purpose, we adapted the coding scheme developed by Berkenstadt et al. [78] for analyzing the clinical content of handoff communication. The framework included a comprehensive list of specific clinical elements relevant to critical care patients (See Table 4 for all the categories and their description).

Table 4. Clinical content of communication exchanged during nurse handoffs (from [78]).

Content Categories	Description	Examples of Content Elements
Administrative data	Patient demographics, and patient admission information to the unit	Patient name, age and sex Family background Date of admission Length of stay
Problem List	Medical observations of patient conditions and patient history	Medical and surgical history Reason for admission to unit Current medical problems
Current assessment and plan (including	Patient status and plan related to body systems including neurology,	Neurology: *consciousness and sedation score, extremities, psychological status*

diagnosis)	cardiovascular, respiratory/pulmonary, infection disease, GI/GU, skin	Cardiovascular: *Blood pressure; mean arterial pressure; heart rate; Central venous pressure, rhythm* Respiratory/Pulmonary: *respiratory rate, oxygen saturation, mechanical ventilation* Infectious disease: *Temperature max, Lactic acid, ScVO2 (venous oximetry catheter), Cultures* GI/GU: *Diet, Abdominal status, Input/Output fluid* Skin: *Lesions, redness*
Medications and treatment	Medications and treatments for each body system problem	Regular medications Medications in continuous feeding
Lines and invasive devices	Invasive lines and devices	IV lines and Fluid input Nasogastric tube and input/output Urinary catheter and urine output Endotracheal tube and secretions
Labs	Lab work status	Lab work including blood, sputum cultures etc. performed/ incomplete
Results	Results from lab work and imaging studies	Laboratory results Radiology results
Events during the last shift	Patient unexpected response to intervention	Hemodynamic, respiratory, other
Code Status	Status of patient	Full code, DNR (Do-not-resuscitate), DNI (Do-not-intubate)
Order Review	Checking orders together on patient chart (towards the end of handoff)	Pending and new medication and procedure orders
Tasks expected to be done	Pending tasks	Laboratory test, imaging studies Procedures Consultations Other
Family concerns	Concerns about patient status/ care from family	Family issues/ questions about care process
Special Order	Orders for special conditions	Isolation, fall precautions, restraints
Allergies	Patient allergies	Allergies to medicines, latex, food
Other	Any other situational awareness information that do not fall in the above categories (and unrelated to patient's diagnostic condition)	Psycho-social and contextual dynamics of patient/family

The first author (JA) coded the transcripts for content of clinical communication (using medical reference books with joint consultation with KFA, an ICU physician); given the clinical nature of the data, a nurse collaborator (KDL, an RN, PhD) coded two transcripts (23.2% of total functional units). Comparisons of the coding showed high inter-rater reliability (*Cohen's Kappa*

= 0.97, 94.9% agreement). After discussion and further clarification of the coding scheme, inter-rater agreement reached 100%.

Disruptions in Communication: Communication failures have been cited as a primary contributor to sentinel events and medical errors [1]. We identified the communication disruptions during nurse shift reports to evaluate the quality of communication.

Table 5. Disruptions in communication during nurse handoffs (modified from [27]).

Communication Disruption Type	Definition	Example (from data)
Doubtful information	Communication characterized by uncertainty in patient information and is subject to question	A: "The way, um, I was, uh, helping, uh, I think, um, K said it's a multiple resistance to the ___ and some other stuff that she could not pronounce."
Missing information	Communication characterized by incomplete or loss of information	A: "An NG tube? I don't know. I don't know."
Incorrect/Conflicting information	Communication characterized by inaccurate information and erroneous data	A: "Going into this one." B: "No, they want the, that's what I told you, they don't want to do a, they want a new line."
Repetitive information	Communication characterized by a complete match (duplicate) or similarity in information exchanged earlier in the conversation	B: "You said 3?"
Misinterpreted Information	Communication characterized by inaccurate explanation and understanding of the information	B: "I thought you are suggesting me to tell him not to?" A: "No. That's what he said. Let me wrap it so that you don't get bed bugs."

A disruption was characterized as a breakdown (or gap) during information exchange. For example, failure to share admission information of a newly admitted patient by the outgoing nurse can result in such a disruption. We adapted the information breakdown classification framework developed by Abraham et al. [1, 27] to analyze the handoff communication disruptions. Each functional unit was classified as either "no disruption" or as one of five types: doubtful information, missing information, incorrect/conflicting information, repetitive information or misinterpreted information (see Table 5).

The first author (JA) coded all transcripts for disruptions identified in the conversation; the second author (TGK) coded three transcripts (29.42% of functional units) with a relatively high

inter-rater agreement (*Cohen's Kappa* = 0.76, 97.7% agreement). Differences were resolved by discussion, with final inter-rater agreement reaching 100%.

Inflection Point in Conversations: During data analysis, we observed changes in the structure and content of communication during the latter stages of each shift report. To further examine this, we developed a post-hoc hypothesis, where we identified an *inflection point* in each transcript that signified a conversational transition. For each handoff transcript, the inflection in the conversation was marked as a point in the conversation where there was a clear distinction in the conversational structure and content—the outgoing nurse paused after their information presentation giving the incoming nurse an opportunity to ask questions regarding the presented information. We provide an example how the inflection point was coded in the transcripts.

Table 6 provides a segment of the conversation where an inflection in conversation was identified. After the "that's all" dialogue by the outgoing nurse (see line 4 in Table 6), there was a long pause in the conversation indicating the end of information transfer. This pause was often followed by the incoming nurse's questions regarding the presented information. In the example in Table 6, the questions were related to the administered medications.

Table 6. Example of how the inflection in the conversation was coded.

Speaker	Content	Pre or Post
Outgoing	Ativan 1 milligram titrate to myoclonic seizures or jerks.	Pre
Outgoing	Um, here. Continued, No myoclonic jerks. Continuous one and one,	Pre
Outgoing	do not interrupt patient's sedation	Pre
Outgoing	And that's all.	Pre
Pause in conversation [Inflection Point]		
Incoming	So she's no longer on ….?	Post
Outgoing	She's not on it anymore.	Post
Incoming	Or the propofol?	Post
Outgoing	Or the propofol. [UNCLEAR] DC'd.	Post
Outgoing	Anything else I need to tell you about her?	Post
Incoming	[UNCLEAR]- no	Post

Two authors coded all transcripts (JA, CJB) indicating the inflection point in the conversation, with a high degree of inter-rater agreement (*Cohen's Kappa* = 0.93, 97.56% agreement). Differences were resolved by discussion such that final agreement reached 100%.

The quantitative analysis involved the computation of *mean length of turns* of the speakers, and the *number of turns* to analyze the transitions in communication. Turn length represents the number of consecutive functional units attributed to a speaker before the second participant speaks, while number of turns reflects the switches between speakers during a conversation.

3.5.2.2 *Sequential Analysis*

Verbal data that were coded along the three dimensions, structure, clinical content and disruptions were used for sequential analysis. We used Lag Sequential Analysis (LSA) to analyze the evolution of repetitive patterns within the structure and content of handoff communication. LSA has been widely used in general behavioral research [66, 79], and more specifically in studying physician-patient interactions [65, 80, 81]. [1]We performed LSA only on the structure of communication categories (see Table 3). In order to perform LSA, the structure of communication data was transformed into an antecedent-consequent transition matrix. The raw sequences of structure of communication data included 7 items of outgoing nurse (A) conversational structure, and 7 items of incoming nurse (B) conversational structure (See Table 3). For example, the outgoing nurse would have the following categories: A-Present, A-Seek, A-Propose, A-Critique, A-Accept, A-Revise, and A-Metacognition. In this transition matrix, initial communication structure categories were listed by row (antecedent), and subsequent communication structure categories were listed by column (consequent). Each cell in the antecedent-consequent matrix represents the frequency of transitions between two considered categories (e.g., A-Present and B-Accept with cell count of 5 indicates five instances of A-Present followed by B-Accept conversations).

In order to perform Chi-square analysis on the tables, the sparsely populated rows and columns were eliminated (i.e., those with marginal frequencies less than 35). After the removal of the sparse cells, the following categories remained: "A-Present", "A-Propose", "A-Metacognition", "B-Accept", and "B-Seek" (i.e., a 5 x 5 matrix). We performed a likelihood Chi-square test on the antecedent-consequent transition matrix to ascertain whether the cell frequencies were distributed across the contingency table by chance or not. If the rows and columns were independent, expected cell counts and adjusted residuals were calculated for each

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[1] Performing LSA requires individual cells to not be sparsely populated. Given that there were 15 clinical content categories, the cells were sparsely populated.

cell in the table. Each cell was compared to a criterion value of 2.58 (i.e., $\alpha = 0.01$). Positive values of adjusted standardized residuals indicated that observed values were larger than expected values for each cell, and were evidence that the transition between conversational categories represented by that cell occurred more frequently than would be expected by chance.

4   Results

In this section, we describe the analysis of transitions, interactions and sequential structure that were observed during the verbal handoff communication. Next, we report on the results from our qualitative evaluation that illustrates the use of the body-systems based tool by the nurses before and after handoffs.

4.1   *Transitions during Communication*

Mean length of turns for the outgoing nurse (*M*=3.50, *SD*=1.63) was greater than the incoming nurse for the overall (*M*=1.09, *SD*=0.08) [$t(14)$=5.74, *p* <0.001], pre-[$t(14)$=4.89, *p*<0.01)], and post-inflection phases [$t(14)$=3.78, *p*<0.001]. The mean number of turns across all the transcripts was 59.20 (*SD* = 33.20). The mean number of turns during the pre-inflection phase (*M* = 42, *SD*=24) was significantly greater than that during the post-inflection phase (*M*=17.87, *SD*=17.44) [$t(14)$=3.63, *p*=0.002].

4.2   *Structure, Content and Disruptions in Communication*

Structure of Communication: Conversational strategies during collaborative interaction included: presentation of information (69.7% of functional units), accepting information (16.3%), and seeking of additional information (8.1%). There were limited meta-cognitive (2.5%) or critiquing (0.2%) aspects during these interactions (See Figure 4).

There was a significant association between the speakers and their structure of communication ($\chi^2(6)$ = 1267.03, *p*<0.001), with the outgoing nurse focusing on information presentation (89% of functional units), and the incoming nurse on accepting (59%) or seeking additional information (26%). The structure of communication was significantly different between pre- and post-inflection phases ($\chi^2(6)$ = 34.27, *p* <0.0001) with the post-inflection phase having 20% less information presentation and 50% more information seeking than the pre-inflection phase.
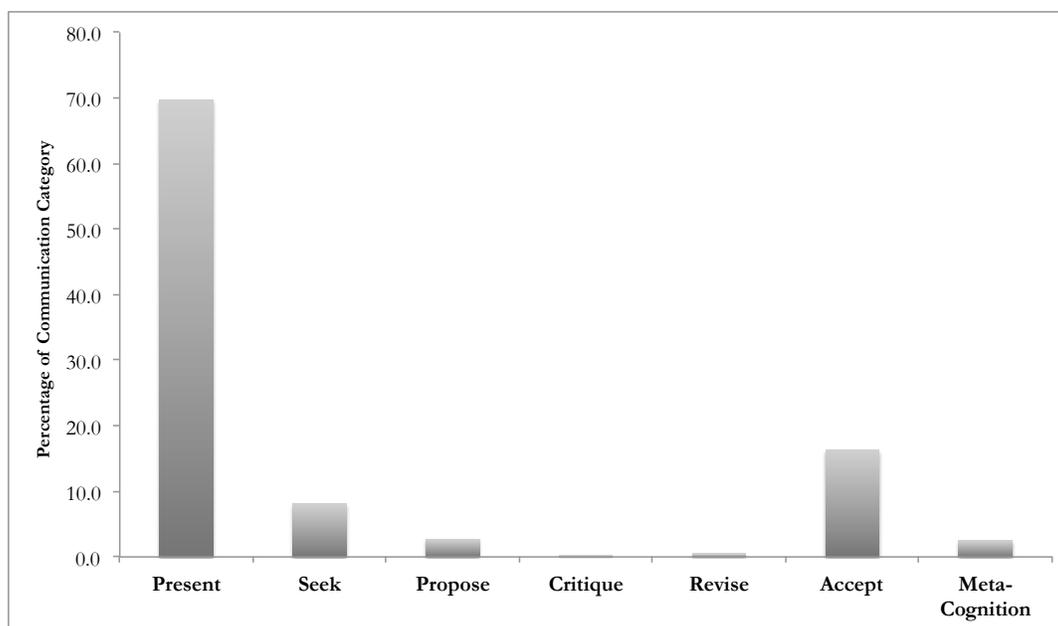
Figure 4. Distribution of the various categories related to the structure of communication.

Clinical Content of Communication: The content of communication was distributed across information related to current assessments and plan (total=35.1%) related to the cardio-vascular (7.4%), neurology (7.3%), pulmonary (6.9%) and GI (6.7%) systems; lines (16.0%), medications and treatment (9.6%), order reviews (8.6%), and problems (8.1%). There was limited discussion of labs (1.7%), special orders (0.7%), allergies (0.5%) or code status (0.4%). A summary of the distribution across all the considered clinical categories can be found in Table 7.

Table 7. Distribution of the various clinical content categories discussed during nurse handoff communication.

Clinical Category	% of Clinical Content
Administrative data	2.2%
Problem List	8.1%
Current assessment and plan	
CV	7.4%
GI/GU	6.7%
ID	3.4%
Neurological	7.3%
Pulmonary	6.9%
Skin	3.4%
Medications and treatment	9.6%
Lines and invasive devices	16.0%
Labs	1.7%
Results	1.6%

Events during the last shift	1.6%
Code status	0.4%
Order Review	8.6%
Tasks expected to be completed	3.8%
Family concerns	4.2%
Special order	0.7%
Allergies	0.5%
Other	5.7%

There was a significant association between speakers and their content of communication ($\chi^2(19) = 43.91$, $p < 0.001$) with both speakers focusing on lines (Outgoing: 16%, Incoming: 15%) and medications (Outgoing: 16%, Incoming: 15%). Additionally, there was a significant focus by the incoming nurse on order review (13%). The content of communication was significantly different in the pre- and post-inflection phases ($\chi^2(19) = 578.68$, $p < 0.0001$). While the content of pre-inflection conversations focused on lines (19%), medications and treatment (10%), post-inflection conversations focused on order review (31%), and patient/family's psycho-social and contextual dynamics (17%; i.e., "Other" in Table 4)[2].

A preliminary analysis of the comparison between the morning and evening handoffs can be found in Appendix 1.

Disruptions in Communication: 58 disruptions in communication were identified (3.1% of functional units). Most of these disruptions were caused by either doubtful or missing information (37.9% each), followed by repetitive information (15.5%), incorrect/conflicting information (6.9%), and misinterpreted information (1.7%) (See Figure 5). There was no statistically significant association between the speakers and disruptions ($\chi^2(1) = 0.67$, p =0.41), or between the phases of the conversation ($\chi^2(1) = 1.89$, p = 0.17).

Based on a linear regression analysis, we found that disruptions were not associated with the mean length of turns for either the outgoing or the incoming nurse ($p > 0.05$). Additionally, over 80% of the disruptions occurred when the length of the previous conversation was less than or equal to 5 functional units. In other words, longer conversation length did not lead to increased communication disruptions.

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[2] Comparisons based on the derived groups (i.e., speakers, pre- and post-inflection) were based on normalized percentages of the categories within each group.
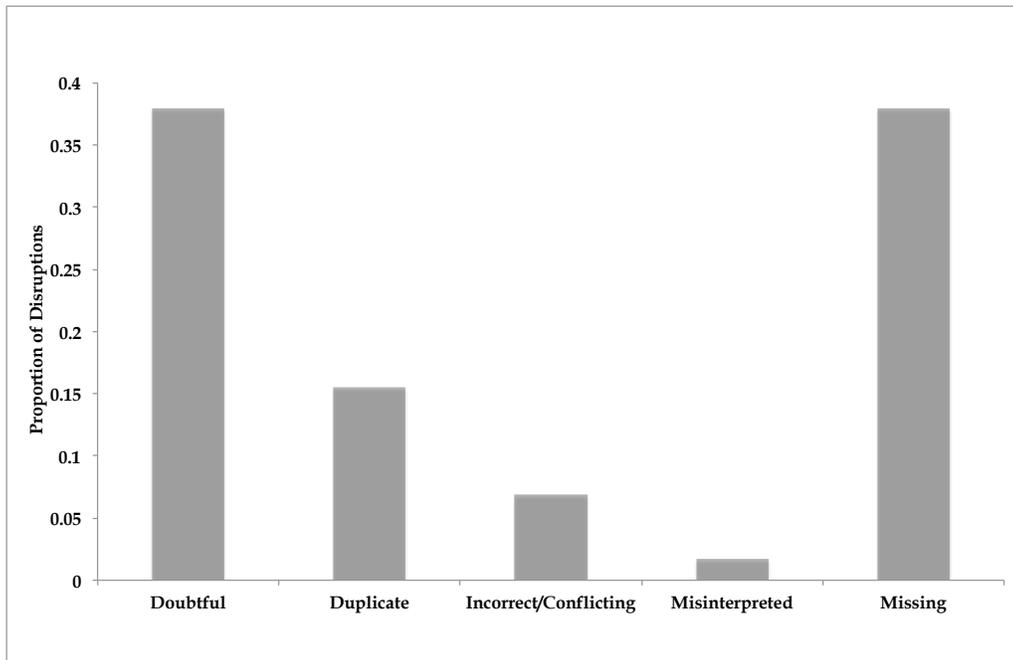
Figure 5: Distribution of the various types of disruptions (See the list of disruption categories in Table 5).

4.3   Patterns within the Structure of Communication: Sequential Analysis

Chi-square likelihood ratio tests were significant for the transition matrix representing the structure of communication—indicating possible association between the structure of communication categories (χ^2 (25) = 265.93, $p < 0.001$). There was a positive relationship between six pairs of categories (see Table 7, cells shaded in grey). These were ("→" indicates followed by): (1) A-Present → B-Accept; (2) A-Present → B-Seek; (3) B-Accept → A-Present; (4) B-Accept → A-Meta-Cognition; (5) B-Accept → A-Propose and (6) B-Seek → A-Present.

These sequences on structure of communication can add nuance to our understanding of interaction between the nurses. For example, the outgoing nurse's role is most often to present information to the incoming nurse, who accepts or seeks additional information (sequences: *A-Present → B-Accept*; *A-Present → B-Seek*). The incoming nurse's conversations are dominated by "accept" conversations (i.e., acknowledgments), which are followed by the outgoing nurse presenting new information (*B-Accept → A-Present*), offering insightful responses (*B-Accept → A-Meta-Cognition*) or proposing new information (*B-Accept → A-Propose*).

Table 8. Frequencies, conditional probabilities, and adjusted standardized residuals for the overall structure of conversation variables (the significant pairs of cells are shaded).

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	A-Meta Cognition	A-Present	A-Propose	B-Accept	B-Seek	Totals
A-Meta Cognition	1 0.02 −0.10	34 0.80 1.3	1 0.02 − 0.12	6 0.14 − 0.26	0 0 − 1.75	42
A-Present	21 0.01 − 3.58	821 0.67 − 6.39	18 0.01 − 4.78	240 0.19 **7.31**	111 0.08 **6.12**	1211
A-Propose	0 0% − 1.11	29 0.64 − 1.17	4 0.08 2.36	10 0.23 1.21	2 0.04 − 0.64	45
B-Accept	19 6.88% **4.90**	239 86.59% **5.96**	17 6.16% **3.96**	0 0% − 7.84	0 0% − 4.90	275
B-Seek	3 2.5% − 0.01	96 80.0% **2.64**	5 4.17% 1.14	10 8.33% − 2.18	2 1.67% − 2.25	116

Two of these sequences were symmetric (and bidirectional), i.e., transitions occurred in both directions. These were: (a) *A-Present, B-Accept* and (b) *A-Present*, *B-Seek*. These symmetric, bidirectional sequences provide evidence for the presence of longer sequences that contain Present-Accept and Present-Seek transitions, showing consistent interactivity during handoff communication. For example, there are likely to be longer sequences of [*A-Present*, *B-Accept*, *A-Present*, *B-Accept*…] and [*B-Seek, A-Present, B-Seek, A-Present…*]. Further evidence for interactivity also exists in the fact that consecutive conversational categories were not spoken by the same speaker, showing the absence of long monologues. In one of our interviews, a nurse remarked that "*whenever, say the nurse is giving report, she may say something that triggers something that may lead to additional questions. Let's say she says his CVP (Central Venous Pressure) has been 2 or 3 and I then ask - is his heart rate elevated? Is his blood pressure lower? I automatically think of volume status.*"

4.4 Qualitative Evaluation of Nurse Shift Reports

In this section, we report on our results from the observations and interviews that add insights on the nature of handoff communication using the system-based tool. Primarily, we focus on the nurse handoff workflow and tool use.

Nurse handoff communication was situated within the clinical workflow of the nurses. As has been previously reported regarding resident handoffs [1, 82], nurse handoffs in the MICU

consisted of three phases: a pre-handoff phase, a handoff phase and a post-handoff phase. During the *pre-handoff* phase, nurses focused on completing the patient care tasks and activities, updating the EHR, and other documentation efforts. As the body systems-based structure of handoff tool supported the constant update during the course of their shift, it was a "live" document and required minimal updates (and additional effort and time) prior to the shift report (i.e., supporting information updates). The *handoff* phase was primarily focused on the exchange of patient related information. In addition to the structured presentation, there were also informal information exchanges that provided contextual information for smooth care transitions. For example, an outgoing nurse asked the incoming nurse to be on alert for an "unstamped" physician order that was sent to the pharmacy. The outgoing nurse also advised the incoming nurse to re-send the order such that patient medications can be administered in a timely manner. Such exchanges highlight the role of contextual and situated information for the incoming nurse to more effectively perform their post-handoff tasks.

The *post-handoff* phase was primarily focused on the incoming nurses' tasks such as patient chart review, nurse-physician and nurse-respiratory therapist communication (in instances where the patient was on mechanical ventilation) regarding the patient's care plan.

One of the important takeaways from our interviews and observation sessions was how the nurses used the body-system based handoff tool. Most nurses described the body-system based tool as an effective mechanism to develop a holistic overview of the patient—both in their roles as an incoming and outgoing nurse. For example, one of the nurses remarked that the patient information on the EHR system is typically fragmented across multiple sources, "*forms on the EHR are not consistent, it doesn't show up and it [information] is in multiple places,… hard to find.*" As a result, the handoff tool provided a standardized template for gathering and organizing the information for presentation during handoffs. Additionally, as previously described, the handoff tool was constantly updated during the shift and integrated into the nurse workflow. One of the nurses stated that the body-systems based tool helped to "*review the systems from head to toe, highlight any changes during my shift, and order review.*"

In addition to being used for information updates during the shift, the handoff tool helped them in *structuring the discussion* during handoffs. Most nurses described that the standardized structure of the tool helped them in having a consistent and systematic conversation, in spite of

the variability within patient, clinician or other contextual aspects. Several nurses also commented on the role of handoff tool as a *cognitive aid*, especially to support information seeking and documentation in preparation for handoffs.

4.5   Summary of Results: Nurse handoffs

We used a new methodological framework, sequential conversational analysis, to evaluate nurse handoff communication. The SCA framework based analysis showed differences between the outgoing and incoming nurses' conversational patterns, conversational strategies and content of information exchanged during the handoffs. Analysis of conversational strategies showed significant interactivity during conversations with *limited monologues*. There were *two distinct phases in the conversation* based on a shift in the conversational pattern and strategy. While the pre-inflection phase involved *information presentation/acknowledgment*, the post-inflection phase consisted of *interactive review and revision*. Predominant patterns of information exchange involved *information presentation by the outgoing nurse followed by acknowledgments* (and acceptance of presented information) by the incoming nurse with *limited focus on evaluation or reflection regarding the exchanged information*. While outgoing and incoming nurses used different conversational strategies during handoffs, these differences had no significant effect on causing disruptions in conversations. Correspondingly, longer monologues by a speaker did not lead to more disruptions. Clinical content during pre-inflection conversations was related *to information regarding lines and patient medications*, while post-inflection conversations were related to *order reviews and discussion of the patient/family's psycho-social and contextual aspects, unrelated to patient clinical condition*. Additionally, the use of the body-systems based tool was perceived to enhance a nurse's ability to quickly develop a holistic perspective of the patient contributing to thorough handoff communication.

5   Discussion

Care transitions have been identified as a vulnerable period during care delivery with risks for communication breakdowns [83]. However, there is a lack of comprehensive understanding of the nature of communication during handoffs [33]. The current focus on handoffs has centered on "information transfer," with limited focus on the nature and patterns of the dynamics of such an information transfer [31, 32, 49]. Although one of the goals of handoffs emphasizes the importance of ensuring "common ground" [63, 84] or a shared understanding of the patient case

between clinicians [85], there has been limited investigation on the *collaborative aspects of handoff interactions* [86-89]. Using the SCA approach, we investigated *the process and structure of information sharing* between the incoming and the outgoing nurses.

Based on our results, we describe two aspects of conversational patterns—the nature of *interactivity* and *collaborative effort* during nurse handoffs, and we highlight the potential of the SCA framework for investigating temporal verbal interaction in pairs and small groups.

5.1   *Interactivity and Collaborative Effort*

Nurse handoffs have primarily been characterized as an unidirectional transfer of information (from the outgoing to the incoming nurse) [15]. Our analyses showed that nurse handoffs are relatively *interactive*. We use the term, relatively interactive to highlight that the incoming nurses' interactions during the conversation are in the form of acknowledgments of receiving information (e.g., "OK"), rather than any confirmatory processes (e.g., "read back" of presented information, as is often the case in Air Traffic Control communication). Though TJC suggests the use of read-backs as a mechanism for effective grounding and interactivity during handoffs, we found no evidence for the use of this strategy in our data [63]. This is likely because the narrative presentation style used by the outgoing nurses may not be amenable to a stringent read-back strategy [20].

Prior research has provided evidence on the importance of two-way conversation and interaction between nurses to promote team cohesion, teaching, and collaborative reflection of patient care tasks of the previous shift [36]. Our results point to a two-way interaction between nurses with limited reflective or critical review of presented information (see section 4.2). Researchers have shown that explicit metacognitive activities can improve the reasoning process leading to effective joint actions and improved collaborative activities [90-92]. Although limited, the transfer of meta-cognitive effort observed in our data can potentially minimize opportunities for bringing in a "fresh eye" perspective—often considered to be a positive aspect of handoffs enabling the detection and recovery from errors [93]. It is also relevant to mention that during handoffs (and similar care transition events), clinicians perform a balancing act between information comprehensiveness and limited available resources (i.e., time and effort). However, the transfer of outgoing nurse's metacognitive activities and critiques regarding patient

assessment and plan can improve shared decision making, potentially resulting in better continuity of care [94].

Closely related to interactivity is the concept of *collaborative effort* for achieving grounding (or shared understanding) during communication [84]. Based on our analysis, we found that the mean length of turns for the outgoing nurse was greater than that of the incoming nurse, highlighting the incongruent distribution of effort during information sharing. In other words, it seems that the burden of collaborative effort is skewed towards the incoming nurse where the incoming nurse has the task of receiving, filtering, and processing the presented information. This highlights the predominant role of the outgoing nurse in these conversations, and the relatively lower overall collaborative effort between the nurses.

Morrow et al [64, 95] reported similar results regarding differential collaborative effort between speakers during air traffic controller communication. They found that reduced turn length (and therefore increase in the content presented in a single message) lead to reduced common understandings between speakers. Using a collaboration scheme that supports natural transitions in communication has been suggested as a potential strategy to balance the collaborative effort. In nurse handoff contexts, it is potentially possible to break the information presentation into shorter installments; for example, the outgoing nurse can present information on a single body system, and then allow the incoming nurse to interject (or ask clarification questions) before presenting the next body system. These shorter communication spans can increase the number of turns, but provide more opportunities for clarifications, and balance the overall collaborative effort.

5.2   *Significance of using the SCA Approach for Studying Verbal Communication*

In a recent commentary, Enrico Coiera argued for a paradigm shift in the design thinking related to informatics—arguing for the importance of understanding the dynamics of communication for designing information systems in healthcare [96]. His arguments were predicated on how errors in communication lead to clinical morbidity and mortality. He presented a "continuum view" that relied on understanding conversational structure and modeling the flow of conversations. The SCA approach described in this paper mirrors this perspective combining seemingly orthogonal methodological approaches to characterize conversational patterns.

While our focus in this paper has primarily been on analyzing dyadic handoff communication, the general SCA approach can be utilized for investigating any type of clinical communication—e.g., during workflow, decision-making or reasoning tasks. There are two important considerations regarding the SCA approach: *first,* as with any in-depth conversational analysis approach, there is significant effort involved in transcribing, segmenting, organizing and coding the communication content. Researchers considering the use of this approach should account for the time and effort investment. *Second*, the approach requires an interdisciplinary team that includes experts in the clinical subject matter, communication, and statistical analysis. Nevertheless, the SCA approach provides an opportunity to conduct in-depth analysis on interactive conversations, helping in the identification of temporally situated, and repetitive patterns in language.

5.3   Conclusion and Limitations

The role of effective handoffs in ensuring the quality and safety of the patient care is well recognized [97]. Using a novel SCA framework, we identified several nuances of the nurse handoff communication that can have a significant impact on patient care across the care continuum. Insights on the nature and characteristics of handoff communication such as its inherent interactivity, two-phased communication processes supporting different functions can inform the development of *training and design interventions* for improved handoff communication. For example, training interventions can focus on educating nurses on the importance of transfer of self-reflective and metacognitive aspects. Learners who engage in self-reflective and critical thinking (i.e., metacognition) have been found to be better at processing and storing new information. Several tools have been developed for nurses that help in critiquing diagnosis and care plans [98], and for improved judgment and reasoning regarding patient conditions [99].

In terms of design interventions, information on handoff tools should highlight the critical and noteworthy clinical events related to patient treatments, systems-based assessment and plan, and orders within the context of the overall patient condition and status. This work extends previous work that argues for the need for considering the social and contextual aspects of handoffs while designing tools and strategies for handoffs [32]. The presentation of information using the body-system or medical format allows for a holistic overview of the patient, and also provides a

framework for the receiver to detect potential discrepancies within the presented data. For example, the handoff tool should allow for easy flagging of key pieces of information that may require a "fresh eye". Additionally, tools must provide support for various phases in the conversation—for example, the discussion of the tasks (i.e., post-inflection phase in our study) needs to be interactive and streamlined to aid nurses to provide a more-comprehensive and collaborative care. The SCA approach, though exploratory, provides a viable mechanism for characterizing the evolution of such conversations in pairs and small groups.

We acknowledge the following limitations of our exploratory study. *First*, we did not evaluate the impact of unresolved disruptions, and the unintended effects of the use of the specific nurse handoff tool on clinical outcomes. Given the focus of this paper was on the development and use of the SCA approach to first identify the nature and quality of nurse communication during shift changes, we hope to assess the impact of the disruptions and unintended consequences related to the tool in our future work. *Second*, we did not evaluate the non-verbal cues (such as gestures, or direct eye contact) that are likely to have had an impact on the quality and efficacy of grounding during communication. While we did make field notes regarding some non-verbal cues, they were not detailed enough as those captured using video recordings or through simulated scenarios in experimental settings (see e.g., [100]). While we acknowledge that non-verbal cues have a significant role in interactive communication, the constraints of the clinical environment (i.e., the intensive care unit) and the institutional restrictions prevented the video recording of our sessions. Additionally, we also did not perform any secondary analysis based on the expertise of the nurses, or weekday/weekend handoffs as we used a relatively small sample of handoffs for our analysis. *Third*, the nurses used the body-systems based tool for their handoffs in the MICU. The results presented in this paper are likely applicable only to critical care settings (such as surgical intensive care unit, transplant care unit etc.) that follow a system-based information format.. *Fourth*, we only evaluated the metacognitive processes during handoff communication. It is possible (and likely) that the nurses engaged in metacognitive activities on their patient care activities prior to handoff communication. More research is needed to establish the role of metacognition during a care transition discussion, and its potential effects on the quality and safety of ensuing patient care activities. Finally, we would also like to highlight the fact that the focus of this paper was on highlighting the applicability of the SCA approach in characterizing the nuances of interactive nurse handoff communication. The case study was a single site study,

and further research maybe required in drawing generalizable conclusions regarding the nature and patterns of nurse communication. However, we have identified several nuances of communication that could result in concerted research efforts.

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