Chapter 15
Clinical Artifacts as a Treasure Map to Navigate Handoff Complexity

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Introduction

Why is handoff communication such an important and difficult issue to tackle in healthcare? First, let's look at why it is important. Poor teamwork and communication are associated with patient safety errors, inefficient use of resources, and excessive lengths of stay [16, 26, 29, 42, 53]. These are all critical foci of any quality and safety initiatives and are increasingly important in the context of Accountable Care Organizations and payment reform. Transitions of care are a time of heightened vulnerability to errors and delays in care [10, 39, 40].

Transitions of care occur across clinical settings and some are primarily driven by a change in the patient's physical care setting, such as: discharging a patient from the hospital to a skilled nursing facility, a primary care provider referring a patient to a specialist, or transferring a patient from the emergency department to a hospital unit. Transitions of care also occur when a patient's physical care setting does not change

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but the providers caring for the patient change, such in the hospital setting. Within the intensive care unit (ICU), due to the continuous demand for monitoring and care, a transition of care typically occurs every 12-h when each patient is "handed-off" from the outgoing provider to the incoming provider and this process occurs for each discipline (e.g., nursing, medicine, respiratory therapy). Handoff is a formal structure used for clinical communication during transitions of care and is one of the most routine and frequent clinical activities in an inpatient setting [15]. In 2010, Patterson et al., defined handoff as: "The process of transferring primary authority and responsibility for providing clinical care to a patient from one departing caregiver to one oncoming caregiver" [37]. One of the central purposes of the handoff event is to establish common ground between clinicians who are transferring primary authority and responsibility and this process occurs explicitly through conversations and implicitly through shared handoff documentation tools [18].

You may ask, if handoffs occur so frequently, why is it such a complex process? An ICU transition of care does not involve a change in the physical care setting but it does involve two specific variables that significantly increase its complexity: (1) the need to establish common ground of high-volume critical care data and (2) the need to coordinate care among a multidisciplinary team. Common ground is a measure of the knowledge shared between two individuals [5]. ICU patients have high acuity and demand continuous and intense monitoring, which translates to a high-volume of clinical data. High-volume clinical data requires a significant amount of clinician time, attention, resources *and* critical thinking to analyze, filter and interpret for clinical significance. During each instance of a handoff a clinician must prioritize and convey layers of data, information, and knowledge within a temporal story-line to establish common ground with the other clinician. This typically occurs under extreme time pressures. The nature of critical care requires significant knowledge and expertise; this shared knowledge and expertise among critical care clinicians eases the complexity of discussions because it is a form of common ground established prior to the handoff encounter [7]. However, there remains a need to establish common ground for the high-volume of data and information generated during a 12 h shift for an individual patient.

Coordination of care among a multidisciplinary team complicates the effort and complexity of establishing common ground. Handoffs require communication of care plans and decisions between providers and across multiple disciplines (i.e., health professionals) that are responsible for patient care tasks [7, 10, 12, 31, 32, 39]. In reality, these are multiple parallel *and* consecutive conversations that lack formal methods for integration. We know that the increased frequency of handoff is associated with increased patient complications and longer hospital stays [23]. The potential for information loss and miscommunication is apparent at each subsequent parallel and consecutive interaction. The often cited, and highly accurate, analogy is the game of "telephone". Understanding the information flow that results from these interactions is critical to develop effective computer-based tools that support the communication and coordination of patient care in a multi-disciplinary and highly specialized critical care setting. First, to set the stage for understanding handoff interactions and information flow, we will present an overview of prior handoff and

communication research. Next, as the focus of this chapter, we will walk the reader through our analysis of the structure, functionality, and content of nurses' and physicians' handoff artifacts. Our analysis will include a discussion of how handoff artifacts can be used to inform the development of an EHR handoff tool that supports the communication and coordination of patient care in a multi-disciplinary and highly specialized critical care setting and implications for future informatics work.

Overview of Prior Handoff and Communication Research

Clinicians within the ICU share a great deal of common ground pertaining to specialized knowledge, yet the care for each patient demands a robust and immediate knowledge of critical and highly complex data. The specific information conveyed during a handoff is often dynamic, patient-specific and conversational, such as information about a patient's plan of care, medication reconciliation, family issues, transport logistics, test results, follow-up care, and advanced care directives [15]. The nature of this dynamic, narrative information poses challenges for the development of structured handoff documentation tools, particularly tools shared among multiple disciplines. However, the types of content discussed should be amendable to categorizations and structured organization in automated tools. The Clinical Communication Space Theoretical Framework is useful to understand why it is challenging to develop tools that structure information and facilitate understanding and communication in the clinical setting. Dr. Enrico Coiera first described the Clinical Communication Space as a continuum along two axes – the amount of shared understanding (i.e., common ground) and the type of interaction (i.e., communication or information task). In this context, Dr. Coiera defined pre-emptive grounding and just-in-time grounding as methods to reach common ground. During Pre-emptive grounding "agents can share knowledge prior to a specific conversational task, assuming that it will be needed in the future. They elect to bear the grounding cost ahead of time and risk the effort being wasted if it is never used. This is a good strategy when task time is limited" [7] During Just-in-time grounding, "agents can choose to share only specific task knowledge at the time they have a discussion. This is a good strategy when there are no other reasons to talk to an agent. For example, if the task or encounter is rare, it probably does not make sense to expend resources in the anticipation of an unlikely event. Conversely, it is a bad strategy when there is limited task time for grounding at the time of the conversation" [7]. The optimal balance between standardized pre-emptive grounding and dynamic just-in-time grounding in the clinical setting remains unknown and is likely multifactorial.

Standardization is recognized by the Joint Commission as a solution to ensure high quality care and maintain patient safety during handoffs and intra- and interdisciplinary communication [1]. Standardization of nursing handoffs has been associated with increased communication of crucial information during handoffs, such as events from the previous shift and treatment goals for the next shift [3].

The Joint Commission and others recognize that safety is a property of systems as opposed to the individual components of care [1, 15]. Distributed Cognition, a theoretical model that posits that knowledge is distributed through the individuals (e.g, clinicians) and artifacts (e.g., computer and paper-based tools) within an activity system (e.g., ICU), supports that well-designed handoff documents and EHR tools reduce the need for clinicians to remember large amounts of information, grounds the coordination of clinical work, and, therefore, reduces information loss [21]. Paper-based documentation suffers from illegible handwriting and barriers to accessibility by multiple clinicians and from remote locations, all potential sources of error in clinical work. Computer-based documentation may reduce the need for clinicians to interrupt each other when attempting to access information [7]; yet, inaccurate data often persists, is difficult to correct, and may have broad and far-reaching consequences if not detected [44]. To support collaborative work, well-designed EHR tools embed the functionalities and infrastructure of the paper they were intended to replace [51]. With the proliferation of EHRs, methodologies from the field of computer-supported cooperative work (CSCW) are increasingly used to understand healthcare work [51]. Successful strategies include the analysis of personally developed artifacts and their use to inform the development of EHR modules that support existing workflow [7]. Insights gained through such qualitative analysis include knowledge of the functions that paper-based tools perform beyond simply conveying information. This knowledge guides the design of collaborative tools and guards against many unintended consequences that surface when paper-based systems are replaced with computer-based systems [51].

Several institutions have developed electronic handoff tools to support patient handoff communication [18, 47, 49], although few have evaluated tools for their impact on clinical processes and patient outcomes. One of the few quantitative evaluations of handoff suggests that computer-based handoff tools can reduce errors [38]. Recent systematic reviews of the handoff literature have shown a lack of consensus and poor definition of the purpose and concept of handoff [6, 37]. Patient safety literature calls for the standardization of handoffs, but the meaning of handoff standardization remains unclear, specifically in the context of the simultaneous multiple purposes that the handoff process serves in the clinical setting [6]. Unfortunately, handoff literature is saturated with anecdotally suggested strategies and mnemonics, increasing the need for high quality handoff research studies that link standardization strategies to patient outcomes to direct evidence-based care [6, 41].

Most handoff literature only focuses on the intra-disciplinary activities of handoff [38, 41, 48, 49]. Health care reform and its focus on coordinated and accountable care will necessitate expanding this myopic focus that is pervasive in the clinical literature. Without doubt, in-depth examination of the handoff process for each clinical discipline (e.g., physicians, nurses) is a significant activity that will contribute to understanding and improving handoffs. From a system perspective (and, let us not forget, the perspective of the patient), handoff is a ‘parallel play’ process. Nurses, physicians, and other health professionals perform handoff adjacent to each other with minimal interaction or influence between the healthcare disciplines. As these siloed conversations occur, handoff information follows a complex and

winding path that is not dominated or coordinated by one particular professional group. Of course this is true! Handoff information consists of data for the *same patient*, but that patient is being cared for by different providers with different workflows and different responsibilities. These unique, complex, and winding paths alter depending on the type of handoff and the clinicians involved. The flow of patient information is often coordinated by two or more influential providers from nursing, medicine, or pharmacy [2]. As key information flows between these influential providers and parallel handoffs occur, examining information gaps and overlaps is a significant activity that will contribute to a broad and systemic understanding and improvement of handoff. With this notion, EHR tools that support handoff of multiple disciplines while enabling the sharing and reuse of pertinent patient data between disciplines may be useful to increase the efficiency of handoffs, decrease information loss, and ensure patient safety [13]. To examine and compare the gaps and overlaps in information discussed and documented between parallel handoffs and overtime for an individual patient, we first need to be able to define what information we intend to compare. In other words, how does a researcher evaluate if the same clinical information that was discussed during the nurses' morning handoff was discussed during the physicians' handoff the night before? It starts with defining types of clinical information. In this chapter we look at how we can define types of information to compare the purpose, structure, and utility of handoff documents. A subsequent chapter uses similar methods to compare the information discussed in parallel handoffs per patient across disciplines.

To define types of handoff information, we use the Interdisciplinary Handoff Information Coding (IHIC) framework. This framework is an empirically based coding framework that provides lists of handoff content that overlaps between nurses and physicians and handoff content that is specific to each discipline [13]. Recently, the applicability of this framework has been extended to analyze information discussed during rounds in an ICU setting, in addition to handoffs [11, 25]. Use of this coding framework helps delineate types of handoff information that are important to nurses and physicians and type of information that are critical to a specialized setting, such as the ICU.

The Cardiac Intensive Care Unit: World-Class Cardiac Care Peppered with Frequent, Complex, and Parallel Handoffs

The study of cognitive complexity and patient safety does not take place in a vacuum. It is intensely integrated within the setting being studied. In this book you will read about many studies and many intensive care units. The Cardio-Thoracic Intensive Care Unit (CTICU) discussed in this chapter exhibits all dimensions of a highly complex system while managing to deliver high quality care. The specific unit we studied and will refer to is a 21 bed CTICU at a large urban medical center. This unit is recognized for the highly specialized and complex cardiac surgical care that it delivers to the sickest patients from all over the world whom have undergone

cardiac or thoracic surgery. The study that we will discuss was conducted during the spring 2010 and Institutional Review Board approval was obtained prior to data collection. The range of patients cared for in the CTICU are: (a) post-operative coronary artery bypass graft (CABG) surgery patients that typically require protocol driven, short-term intensive therapy and have a length of stay of a few days with an uncomplicated recovery, to (b) heart failure and transplant patients that may require a longer ICU stay and multiple intensive therapies such as an Intra-aortic Balloon Pump (IABP) or a Ventricular Assist Device (VAD) to support the body's cardiac function. These patients on multiple intensive therapies also have less predictable trajectories.

Research Methods to Analyze Handoffs

At each change of shift on the CTICU, patient responsibility is handed-off: (1) between two nurses and (2) between two resident physicians and/or physician's assistants (PAs). These two sets of highly frequent handoff offer a peak into commonly occurring complexities in the CTICU. We spent a considerable amount of time observing and collecting artifacts (i.e., documentation) from these two types of handoff. During our time on the unit, we observed that each nurse was responsible for two patients (one patient if the patient was critically unstable) and worked from 7 am until 7 pm or from 7 pm until 7 am, with equal patient care responsibilities for the daytime nurses as the nighttime nurses. Nursing handoff occurred twice a day at the 7 o'clock hour and lasted between 15 and 30 min for each patient. The residents and PAs functioned in the same role as each other with the same patient care responsibilities and coordinated patients, schedules, and handoffs mirroring that of the nurses. The residents and PAs worked daytime shifts as well as rotating evening and overnight 'on-call' shifts every few days. Handoffs also occurred twice a day for the residents/PAs at about 6:30 in the morning and anytime between 5:30 and 8:00 in the evening. During the day, each resident/PAs was responsible for 4–6 patients at a time. Overnight, fewer residents/PAs were on duty and each was responsible for as many as 11 patients. During our observations, the clinicians used a commercially developed electronic health record (EHR) for clinical documentation, however, not for handoff documentation. Nurses used two paper-based handoff tools and residents/PAs used a locally developed computer-based application that was not integrated with the EHR. We will present and analyze all of these handoff tools in detail later on in this chapter.

Observations are an important method to obtain insight into the culture of a clinical unit, and specific processes or behaviors of that clinical unit, under natural conditions. Over the course of 5 days, we observed how nurses, residents, and PAs used artifacts (i.e., documentation) during the handoff process and collected the handoff artifacts used by the clinicians. Purposive sampling was used to maximize the variability of handoff processes by CTICU patient type in the context of the patient's clinical status and expected prognosis trajectory. In other words, we sought to

observe the handoff for patients that were on the CTICU for a wide-variety of reasons and were experiencing a wide range of health and sickness states and steps towards recovery. For example, we observed patients undergoing routine cardiac surgery and patients that needed emergent cardiac surgery; stable patients with a short expected length of stay and unstable patients with a variable/unknown expected length of stay; and patients undergoing long-term cardiac surgical care, such as cardiac transplant patients. Each morning we asked the charge nurse for a list of patients whose handoffs we should target based on the types of patients we still needed to observe. We observed a total of 9 changes of shifts in the morning and in the evening; during each change of shift we observed between 1–2 nursing handoffs and 1–2 resident/PAs handoffs. We did not target nurses, residents, or PAs based on their expertise or experience. Due to the highly specialized nature of the CTICU, we found that most of the nurses and PAs had at least 3–5 years of clinical and critical care experience, often on that particular unit. None of the nurses or PAs observed had less than 6 months experience. Unlike nurses and PAs, the residents rotate throughout different clinical settings as part of their training. Residents have some acute care (and sometimes critical care) clinical experience before entering the CTICU, but overall, due to the structure of resident training programs have less experience in the CTICU than nurses and PAs.

When permissible by the clinician, we collected the original paper-based artifacts (or made photo-copies of the artifacts when necessary) that the clinicians used during handoff and throughout their shift. These documents were typically filled with handwritten notes taken while receiving handoff at the beginning of their shift, throughout their shift, and for giving handoff at the end of their shift to the oncoming clinician. Therefore, the artifacts collected reflect data entry that lasted throughout the shift. In the case of the resident/PA computer-based handoff tool we collected the paper-document that each of them printed out before each shift. All of the handoffs were also audio-recorded, but the focus of this paper is on analysis of the documentation.

Handoff Artifact Analysis

Artifacts are useful for distributing information through a system [34]. It is precisely that information, and more specifically the flow and distribution of it at given points in time, which we want to understand. Observations of a handoff tend to miss information of clinical inferences, processes, and implied tasks that are a known – or assumed – between experienced clinicians and may not be stated out-loud. Asking clinicians about their handoffs is subject to recall bias. The addition of artifact analysis adds a third dimension (i.e., triangulation) to balance out the weaknesses of observations and recall and contributes to a comprehensive view and understanding of the handoff process. Artifact analysis has been successfully used to study user-designed information tools that support communication and care coordination for the purpose of developing user requirements and exploiting the

functionality of the artifact in the environment [20, 51]. The distributed cognition framework characterizes divisions of labor, gaps and overlaps in domain knowledge, the representation of information within artifacts, and patterns of interactions within a system [52]. Specifically, artifacts represent a component of a system's distributed cognition and the analysis of artifacts is informative along two dimensions to understand the nature of clinical care cognitive work: (1) clinicians' creation and use of artifacts to inform clinical work, and (2) information representation with artifacts that describe the nature of the complex clinical work [34]. To understand these two dimensions of clinical care cognitive work, we combined artifact analysis with semantic coding based on a developed framework for a novel two-step data analysis approach. The first step used observational and artifact analysis techniques to analyze the structure and functionality of the artifacts. Our artifact analysis was also informed from our observations of many handoffs where we observed recurrent (largely invariant) patterns. For the second step, we analyzed the content and discipline-specific properties of the artifacts by coding each using the IHIC coding framework.

The specific methods employed for artifact analysis were based on Nemeth's cognitive artifact analysis methodology to understand distributed cognition within an operating room [24, 33]. Distributed cognition consists of four analyses: user, task, functional, and representational [24]. We identified the user as the clinicians involved in each handoff and the task as the handoff process. Nemeth's methods for artifact analysis are consistent with the functional and representational analysis from distributed cognition. We employed our observations of handoff to identify the functions that the artifact served, such as how the artifact was created and used during handoff. Consistent with representational analysis, Nemeth cites that the artifact's structure and content is a highly encoded representation that describes the complex domain work. Therefore our iterative analysis of the structure and content of each artifact, and triangulation of those findings across artifacts, were essential processes of our artifact analysis [33].

The content analysis was performed using the IHIC coding framework. The IHIC framework was developed based on analysis of handoff content from 36 nursing and physician handoff studies and includes a total of 95 handoff information elements. Forty-six percent (44/95) of the information elements are interdisciplinary content (i.e., elements were part of both nurse and physician handoffs). Thirty-six percent (34/95) of the handoff elements in the coding framework are specific to nursing handoff and 18 % (17/95) of the elements in the coding framework are specific to the physician handoff [13].

An iterative process was used to develop consensus on the artifact analysis and the application of the IHIC coding framework. Based on this iterative process, data collection and analysis was performed until data saturation was reached. Consensus for coding was reached during small group sessions which included a nurse informatician experienced in critical care nursing (SC), two informaticians with cognitive science and human factors expertise (DK, LM), a CTICU attending physician (DJ), a research assistant (AS), and a medical student [12]. During these sessions individuals presented their coding of a subset of handoff artifacts and the group agreed on interpretations of the coding framework. After the consensus for coding

was established, the nurse informatician (SC) performed coding for all handoff artifacts. A physician informatician (3) performed inter-coder reliability on 32 % of the artifacts [12].

What Are These Artifacts and How Are They Part of a Complex, Sophisticated and Paper-Based System?

We analyzed a total of 22 artifacts from the CTICU. There were three types of semi-structured artifacts used during handoff: two types of nursing artifacts and one resident/PA artifact. The two nursing artifacts, a nurse admission 'Kardex' and nurse personal handoff sheet, provided different functionalities. Both of the nurses' artifacts were paper-based with pre-printed semi-structured templates for hand-written notes. The resident/PA handoff artifact was a computer-based tool that was not integrated with the EHR that the residents/PAs printed out and carried with them for reference and to take hand-written notes throughout their shift. We analyzed a total of a 6 nurse admission Kardex, 8 nurse personal handoff sheets, and 8 resident/PA handoff print-outs. The results are presented to reflect the two step analysis: (1) the analysis of the structure and functionality of the artifacts and (2) the analysis of the content of these artifacts using the IHIC coding framework.

How Do Clinicians Use and Organize Artifacts to Coordinate and Communicate Their Work?

The handoff process in the CTICU is largely similar for nurses and residents/PAs. The process consisted of a conversation between the clinician from the previous shift (i.e., outgoing clinician) and the clinician from the next shift (i.e., oncoming clinician) and was supported primarily by paper-based artifacts (including print-outs of the resident/PA computer-based handoff tool) and occasionally by reference to the EHR or other patient care monitors or devices when needed. Our observations confirmed that the artifacts analyzed in this study were the main cognitive adjuncts that the clinicians used and carried with them to record and reference patient data. The nursing handoff usually took place within sight of the patient's room and involved visual references to the patient and therapies provided. The resident/PA handoff usually occurred at the central nurses' station, not in sight of the patient, and rarely involved visual reference to the patient or the therapies provided.

In the following paragraphs we analyze the three artifacts, first discussing the structure and then the content of each artifact. The nurse admission Kardex was a highly structured and information dense sheet that reflected a consistently used process for the documentation of admission information by the nurse and discussion during handoff (see Fig. 15.1). A large portion of the Kardex included structured areas to document events that occurred during surgery such as time spent on bypass, medications and blood products given, complications and necessary interventions.

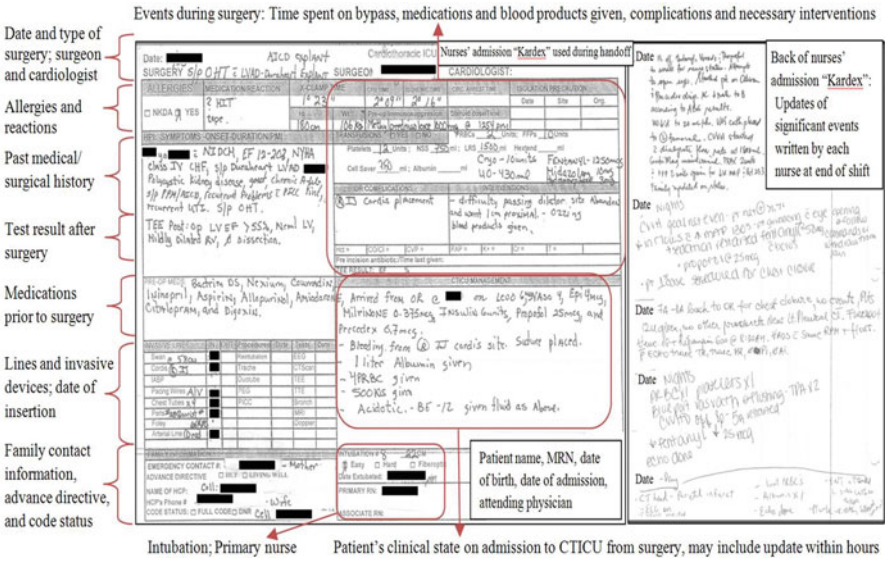

Fig. 15.1 Nurse admission Kardex annotated with descriptions and codes

There was a place to document the patient's medication list prior to surgery and the patient's current CTICU management. The CTICU nurses also wrote on the back of the Kardex, and used additional plain paper as needed, to communicate significant events that occurred during each shift (far right in Fig. 15.1).

During handoff, the outgoing nurse typically began the discussion of the patient by referring to the nursing admission Kardex. The term Kardex is derived from a traditional nursing card indexing system and refers to a paper-based semi-structured nursing tool that provides a synopsis of a patient and is written in pencil so that it could be updated easily for the purpose of communication between nursing shifts [45]. On the CTICU, the nurses' admission Kardex was filled-out once, in pen, for each patient by the nurse that admitted the patient to the CTICU – this nurse was typically designated as the patient's primary nurse who was responsible for coordinating the patient's care. At each subsequent nursing handoff, the nurses' admission Kardex was used as an information source to describe relevant background information about the patient, the surgical procedure, and the patient's clinical state upon admission to the CTICU immediately following surgery. The admission Kardex was kept in a binder at the patient's bedside or immediately outside the patient's room, was not considered a part of the patient's legal record, and was discarded after the patient was discharged. The significant events documented on the back of the Kardex were also discussed during handoff between nurses to communicate important events that occurred to date during the patient's stay in the CTICU. The nursing handoff varied in length depending on the complexity of the patient and the oncoming nurse's familiarity with the patient. For example, if the oncoming nurse cared for the patient the day before, or was the patient's primary nurse, the information on the Kardex was not discussed at all.

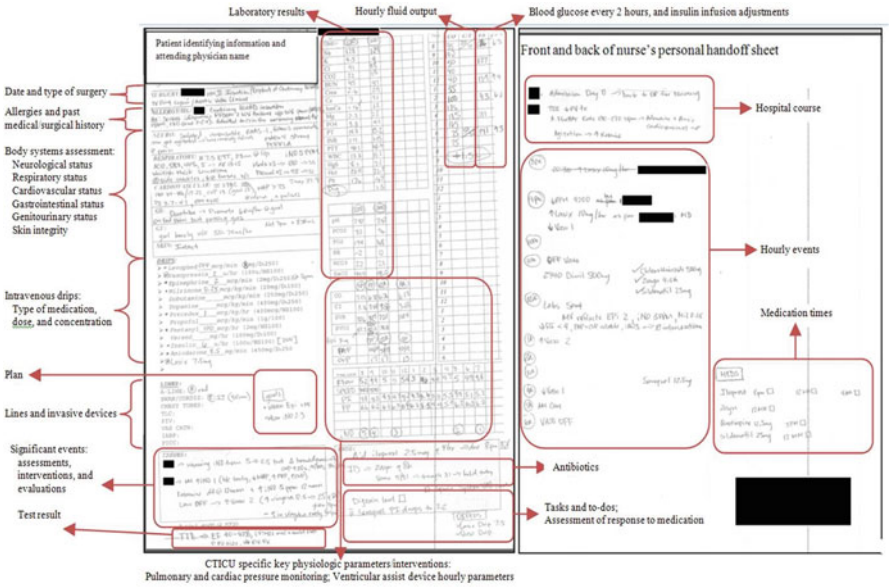

Fig. 15.2 Nurse personal handoff sheet annotated with descriptions and codes

The nurse personal handoff sheet was also paper-based and highly structured (see Fig. 15.2). The assessment of the patient corresponded to the body systems (e.g., neurological, cardiovascular, respiratory) structure. Common intravenous infusions were included in the template with dosage units and concentrations; this structure allowed the nurse to simply enter the dose in the space provided. The bottom of the sheet provided an area for the nurse to document issues and medications. Nurses used this area for a number of purposes such as: significant events, assessments, interventions, medication changes and times, tasks and to-do's, test results, and hourly parameters for interventions such as Continuous Veno-Venous Hemodialysis (CVVHD). As noted in the annotations in Fig. 15.2, the nurses' personal handoff sheet also contained boxes for specific laboratory values measured up to seven times, boxes for hourly parameters for CTICU interventions, and boxes for measuring hourly urine output, chest-tube output and blood glucose. Nurses also used the back of the sheet to document information such as the hospital course, medication times and significant events on an hourly basis throughout his or her shift. In at least one instance on every sheet, medication information was written next to a laboratory value. For example, in Fig. 15.2, the blood glucose values in the top right corner of the front of the sheet have arrows and numbers to the right of them that indicate the change in the intravenous infusion dose of insulin in response to the blood glucose. These types of annotations were also seen to indicate the administration of potassium or magnesium in response to low potassium or magnesium laboratory values. For example, the potassium laboratory value of 3.8 mEq/L was circled and next to it "20" was written, indicating that an intravenous solution containing 20 mEq of potassium chloride was administered. On the same sheet a magnesium laboratory

value of 1.9 mEq/L was annotated with "2 mg", indicating that an intravenous solution containing 2 mg of magnesium sulfate was administered.

During nursing handoff each nurses' personal handoff sheet was used in conjunction with the nurse admission Kardex. At the end of the nurse's shift, he or she used the document as a point of reference and information source to discuss the patient's current clinical state while giving handoff, typically following discussion of the Kardex. Initially, each nurse filled this sheet out at the beginning of his or her shift while receiving handoff. During the course of the nurse's shift, he or she often used this sheet as a cognitive artifact to write down patient data and information relevant to the care of the patient. The nurses' use of this sheet is consistent with the widely accepted definition of a cognitive artifact proposed by Donald A. Norman in 1991: "an artificial device designed to maintain, display, or operate upon information in order to serve a representational function" [35]. The sheet served to coordinate work activities and as a memory aid to represent significant patient issues that may warrant attention during the shift. The sheet was not handed-off to the next shift, but was discarded at the end of the nurse's shift. The information flow of patient data on this sheet took one or many of the following paths: (1) information verbally discussed during handoff was transcribed on the sheet by the receiving nurse, (2) information was transcribed from the EHR onto this sheet, (3) information was written on this sheet and later transcribed by the nurse into the EHR, (4) information was never transcribed into the EHR, (5) information was used as a reference at the end of the shift for verbal handoff to the following shift. Despite the double documentation that occurs between these paper-based handoff sheets and information contained in the EHR, these are highly structured and distinct paper-based nursing handoff artifacts, with consistent data patterns.

The resident/PA computer-based handoff artifact, which was not integrated with the EHR, consisted of four unlabeled free-text boxes that provided minimal structure; yet, social norms influenced the types of information included in each box (see Fig. 15.3). The first box on the far left included the past medical and surgical history, information about the hospital course and the patient's surgery, and test results pertinent to the surgery. The second box typically started with a date and list of the patient's intravenous infusions and may or may not include a dose (never specifying the dosing units). The intravenous infusions were followed by a list of invasive lines and devices which include the date of insertion. Next, there was often a list of the patient's antibiotics, which rarely included the dose, followed by the results of bacterial cultures. The top of the third box often was filled with a problem list, followed by recent events that were delineated by date and often carried over into the fourth box. Often, the recent events were a mix of events, tasks and to-dos and plans. Typically, the last information included was a list of tasks and to-dos which were noted as tasks by the use of an open bracket, close bracket before each task, a common physician practice (e.g., "[ ]f/u TEE result", which means follow-up on the Transesophageal Echocardiogram result) [46]. A list of all active medications was never included on the resident/PA handoff artifact. The hand-written notes on the print-out predominately included tasks and to-do's as well as significant events, plans, and updates about intravenous infusions or test results. They served an instrumental role in coordinating work, but not communication.

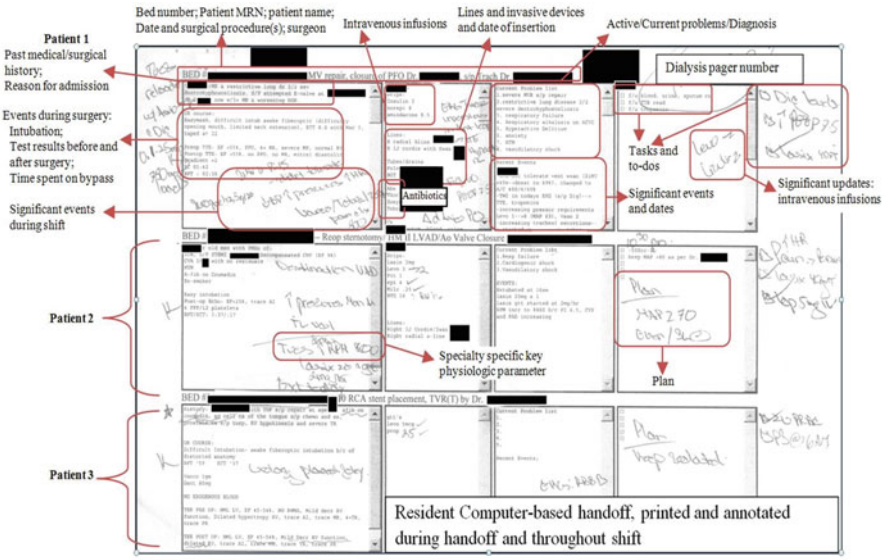

Fig. 15.3 Resident computer-based handoff print-out annotated with descriptions and codes (After this research was completed the CTICU residents began using an EHR integrated handoff application)

The computer-based application was a collaborative documentation tool used by residents and PAs – many individuals contribute to the documentation of a patient over the course of time with no historical record of the previous updates. When information was entered the resident/PA typically included a date; however, there was no record of who entered, deleted, or changed information. The system printed out a document with handoff information for three patients, organized in a landscape format. Figure 15.3 shows a print-out with 3 patients (labeled in the left hand margin of the figure) and the information for patient 1, and some of patient 2, is described and annotated. The computer-based tool was printed out by each resident/PA at the beginning of each shift as a reference and as paper for note taking while receiving handoff and during his or her shift. Additionally, each resident/PA updated the information in the computer-based tool at the end of his or her shift and used that as a reference while handing-off the patient to the oncoming resident/PA.

What Information Is Contained in These Artifacts and How Does it Compare Between Artifacts?

A total of 827 elements were coded on the 22 handoff artifacts. An element was defined as the minimum amount of content that conveyed an independent piece of clinical information, action, or goal. For example, a written reminder to decrease a medication dose was coded as one element because the notation to "decrease" is clinically insignificant without information about the medication dose. Inter-coder

reliability was performed on 7 (32 %) of the 22 handoff artifacts by a physician informatician. This included 2 (25 %) of the nurse admission Kardexes, 2 (33 %) nurse personal handoff sheets, and 3 (37 %) resident/PA computer-based handoff print-outs. The percent agreement for IHIC coding of the handoff artifacts was 83 %.

There were 52 unique codes for the 827 elements on all the artifacts. Thirty-two of these 52 codes (62 %) were included in the nurses' Kardex, 42 out of 52 (81 %) of these codes were included in the nurses' personal handoff sheet, and 27 out of 52 (52 %) of these codes were included in the resident/PA handoff print-out. The IHIC coding framework includes lists of nursing handoff elements, physician handoff elements and interdisciplinary handoff elements. Our instantiation of the IHIC coding framework confirmed this mapping of handoff information elements to discipline specific lists for the artifacts analyzed. No elements from the physician list in the IHIC coding framework were present in the nursing artifacts and no elements from the nursing list in the IHIC framework were present in the physicians' artifacts. Of the 827 handoff elements, 757 (92 %) were interdisciplinary handoff elements. The nurse Kardexes had a total of 309 elements (301 interdisciplinary and 8 nursing), the nurse personal sheets had a total of 261 elements (204 interdisciplinary and 57 nursing) and the resident/PA tool had a total of 257 elements (252 interdisciplinary and 5 physician).

There was a high degree of overlap in the specific interdisciplinary codes present in the nurses' and physicians' artifacts. Table 15.1 presents the codes that were present in at least half of the nurses' handoff artifacts and half of the physicians' handoff artifacts. CTICU specific key physiologic parameters and interventions were present in greater than 50 % of the nursing and physician artifacts. Other information that is critical to the care of ICU patients such as intravenous infusions, lines and invasive devices, and antibiotics were included in both nurses' and physicians' handoff artifacts the majority of the time.

Implications for e-Artifacts

Our analysis of CTICU nurses' and physicians' *paper-based* handoff artifacts demonstrated a non-technical, yet sophisticated, system with a high degree of structure for the organization and communication of patient data that functions to coordinate the work of multiple disciplines in a highly specialized unit of patient care. Therefore, computer-based tools, or "e-artifacts", developed to support handoff must further facilitate the communication of patient data and coordination of work above and beyond the existing paper-based system. Specifically, further research should investigate if mobile and touch-pad devices can support the cognitive functions that paper-based handoff artifacts currently provide to clinicians and determine the sustained need for print-outs from computer-based tools. The artifact analysis also highlighted the limitations of a system that is not integrated with the EHR, including a high degree of transcription and siloed information, that have been linked to ineffective communication and potential sources of error in patient care [8]. Our findings of CTICU social norms, semi-structured handoff templates,

Table 15.1 Presence of codes in >50 % handoff artifacts by type of artifact

Presence in BOTH physician and nurse handoff >50 % of time	
Interdisciplinary[a]	
1. Antibiotics	9. Patient sex
2. Clinicians involved in case	10. Patient's hospital MRN
3. Hospital course/summary/current history	11. Plan
4. Intravenous infusions	12. Reason for admission/transfer
5. Lines and invasive devices	13. Significant events during last shift/overnight
6. Past medical/surgical history	14. Specialty specific key physiologic parameters/ interventions
7. Patient age	15. Tasks/To-dos
8. Patient name	16. Test/procedure results
Presence in ONLY nurse handoff[b] *>50 % of time*	
Interdisciplinary[a]	
1. Active medication list	5. Intake and output/hydration status
2. Admission information and date/hospital day	6. Laboratory Data
3. Allergies	7. Patient date of birth
4. Family contact information	8. Patient weight
Nurse[a]	
1. Blood glucose	6. Neurological status
2. Cardiovascular status	7. Patient height
3. Gastrointestinal status	8. Respiratory status
4. Genitourinary status	9. Skin integrity
5. Medication times	
Presence in ONLY physician handoff >50 % of time	
Interdisciplinary[a]	
1. Active/Current problems/Diagnosis	
2. Patient floor/bed number	
Physician[a]	
1. Cultures	

[a]Discipline mapping from Interdisciplinary Handoff Information Coding (IHIC) framework
[b]Presence in either nurse report >50 % of time or nurse Kardex >50 % of time

and the high degree of common ground and specialty-specific handoff content on nurses' and physicians' handoff artifacts makes the case for the development of handoff tools with interdisciplinary views and reuse of data that are tailored to specialty areas. The concept of tailoring handoff content to settings has been cited elsewhere in handoff literature [1, 36].

Artifacts Coordinate Work and Serve as Communication Tools

Handoff tools function to communicate accounts of historical events deemed significant by the clinicians present at the time of the event. Our analysis demonstrated that these tools coordinated work activities and served as a memory aid.

The observational nature of our study cannot conclude if the highly structured handoff artifacts impacted the largely invariant patterns of the handoff process that we observed. We can conclude from our observations of artifact use during handoff that the structure of the handoff discussion was consistent with the structure of the handoff artifacts. Physicians use team checklists in physician handoff notes to organize, manage, and hand off critical patient-based tasks, and that these tasks are often delineated by a preceding use of open and closed brackets in computer-based systems [46]. The communication function of these handoff artifacts was also evident by the nurses' and physicians' practice of documenting significant events on a shift to shift basis and verbally reviewing those events during handoff. Traditionally, a nursing Kardex and paper-based nursing flowsheets display patient information at a glance [4, 19] and narrative notes tell the story of the patient [9]. Yet, summarization is a difficult problem to solve within an EHR [50]. One of the challenges of summarization is capturing the temporal nuances of patient data. For example, the free-text discussion of significant events on the handoff artifacts included information about the precipitating factors of an event, the event, subsequent interventions, evaluation of the patient response to interventions, changes to the plan of care, and anticipatory guidance for next time the event occurs. Capturing such a rich, and clinically important, story is not possible using all structured data. Our analysis and previous work highlight the need for structured narrative handoff tools, a design that blends coded data elements for selection by the clinicians with options for free-text data entry [27].

Another challenge for the summarization and structuring of handoff data is supporting the individual needs of clinicians. For example, we found that nurses who cared for a patient the previous day did not reference the information on the Kardex during handoff, demonstrating that they did not require the same information than clinicians who were unfamiliar with the patient. This finding indicates that flexibility and tailored displays may be useful for computer-based handoff solutions in specialty units.

The annotation of structured data with free-text to convey temporal information is a well established nursing practice [19] and has been demonstrated as an effective practice in aviation to facilitate critical thinking and maintain the safety of air traffic. This link between free-text annotations and critical thinking has been cited as a rationale for why paper artifacts persisted in aviation after the implementation of computer-based systems [30]. These practices may persist in clinical care because they increase situational awareness and serve an important role in maintaining patient safety. For example, we found that nurses circled potassium values and indicated the amount of potassium that was administered in response to that value; potassium and magnesium are important electrolytes to monitor and replace intravenously in cardiac ICU patients, but an overdose can be lethal. This simple annotation conveys (1) acknowledgment of the critical value, (2) and an unambiguous statement that potassium was administered for that particular critical value, possibly preventing confusion that could lead to a potassium over-dose error. The potential for potassium over-dosing errors, propagated by a series of ambiguous and fragmented displays in an EHR, is well documented in

the informatics literature [22]. A paper-based handoff sheet is not the solution to medication errors for many reasons, including the inability to share information among multiple providers; however, rigorous analysis of the clinicians' strategic use of handoff artifacts to support communication, coordination and maintain patient safety must play a significant role in the development of specifications for EHR handoff tools.

The inclusion of medication information on handoff artifacts took many forms and differed between nurses and physicians. Nurses included many details about the hourly titration of intravenous infusions and the times that medications were due for administration; the residents/PAs specified the type of intravenous infusions and rarely included medication times, only dates. The Kardex provided an area for the documentation of the patient's medication list prior to surgery, but there was no documentation of an active medication list after the CTICU admission in any of handoff artifacts. Medication data within the handoff artifacts did not provide medication reconciliation functionality, but rather a means to highlight certain types of medications, the addition of a medication, and as a cognitive artifact to support medication tasks. This is in contrast to the assumed importance of medication reconciliation as a critical part of patient handoff [14].

Content Overlap as a Marker of Common-Ground for Patient Safety

Our coding using the IHIC framework demonstrated that the content of the nurse and physician handoff artifacts highly overlapped. Most of the handoff items, according to the IHIC framework, were interdisciplinary and many were specific to the specialized CTICU. The high interdisciplinary nature of these items may indicate that these are the items *perceived* by collaborating clinicians as clinically significant to establish common ground for the purpose of maintaining safe, effective, and collaborative care in the CTICU. Our study was not designed to detect information loss associated with compromised patient safety. Our study was designed to detect overlapping clinical content as evidence of common ground between nurse and physician handoff artifacts. Based on prior work described on this chapter, we posit that evidence of common ground in handoff artifacts is associated with safe, effective, and collaborative care.

This is a first attempt to code artifacts using this coding framework to inform the development of a computer-based handoff tool in a specialty setting. Based on our systematic review of nurse and physician handoff that informed the development of the IHIC framework, the structure of the handoff artifacts analyzed for this study are consistent with the general structure of handoff tools in the literature [13]. Consistent with our findings, a few handoff studies also discuss the use of specialty specific data; Van Eaton et al. demonstrated that a handoff tool that supported specialty areas improved workflow efficiency and patient care [49]. Distributed cognition posits that the way in which information is represented is a critical element of artifacts and

the functions and tasks that artifacts support [24]. Consistent with the artifact analysis literature, we found that the structure, organization, and physical location of data elements are critical to understanding handoff artifacts [43]. For example, the physical location of data elements within the document influenced the IHIC coding category because in a given document the same clinical concept (e.g., blood pressure) may be discussed as part of a patient's past medical history, cardiovascular status, vital signs, or a significant event from last night.

The IHIC coding supports the development of interdisciplinary handoff tools that offer tailored views and reuse of data and we suggest its future use for the analysis of nursing and physician handoff content. Nurses tended to include data at a finer level of granularity; therefore, their handoff artifacts contained more data elements than the physicians. Disciplines may need the same type of content but the structure of data input and output may fit the workspace differently for nurses and physicians. Needs may also differ based on clinicians' variable levels of clinical experience. Our findings confirmed that clinicians use siloed discipline-specific handoff documentation. We know that ineffective communication is a patient safety problem within critical care settings [40] and future research should investigate the role of siloed information sources among disciplines as a potential source of error.

A greater commonality of information may exist between disciplines on a specialized unit. Furthermore, a specialized unit may have needs for a greater degree of customization of handoff tools; our application of the IHIC coding framework to the highly specialized CTICU setting supports that notion. The frequent use of specialty specific content in the handoff artifacts, including the consistent use of structured detailed information of events and interventions during surgery, indicated a need to tailor handoff tools to specialty settings. Forcing clinicians to use a less specialized handoff tool that hinders the documentation of critical specialty specific information may, at best, proliferate clinically irrelevant information and, at worst, facilitate information loss.

Treating handoff as a discipline specific process may narrow our view of information flow within a clinical setting. Our findings, while limited by a small sample size, demonstrate the potential value of approaching handoff investigations from a patient-centered view to evaluate the flow of information among all disciplines. The analysis of handoff artifacts from multiple disciplines aids in the understanding of distributed cognition within a setting. We analyzed artifacts that were saved for the duration of a patient's time on the CTICU and used as a communication tool from shift to shift and artifacts that were discarded at the end of each shift. Further research should evaluate the intra-disciplinary content discussed during handoff and the patient-centered information flow of this content between disciplines. Computer-based tools should leverage the type of information that clinicians perceive as clinically significant and, therefore, communicate through paper-based handoff systems. Additionally, the handoff literature should analyze the use of individual clinician's artifacts that are discarded at the end of a shift. Our findings demonstrated that these artifacts support cognitive processes and may maintain patient

safety. The successful development of computer-based systems is dependent on a robust knowledge of the distributed cognition of a system, including the integration of the functionalities performed by paper-based artifacts. Artifact analysis facilitates a multi-dimensional understanding of clinical processes and cognitive work [33, 34]. We found that the analysis was greatly informed by our observations of the use of the artifacts by clinicians during handoff. Additionally, we recommended a triangulated analysis of structure, function, and content of the artifact as a methodology to increase confidence of findings and interpretation of results.

In summary, there is a high degree of overlapping handoff content between nurses and physicians. We recommend the design of patient-centered interdisciplinary computer-based handoff tools tailored to specialty settings to facilitate the establishment of common ground. The IHIC coding indicated that physician, nursing, and interdisciplinary handoff element lists may be employed to organize and manage handoff content. The artifacts analyzed were semi-structured which supported the development of computer-based handoff tools that utilize a structured-narrative design [27]. For example, the documentation of medications on a handoff tool may be amendable to structured data entry and the documentation of 'family contact information' may be best amenable to narrative, free-text data entry. The structured narrative design allows a computer-based handoff tool to fuse unstructured text and coded handoff data elements into a single document, similar to the semi-structured organization on the paper-based artifacts analyzed in this study [27]. The scope of data content desired by clinicians for handoff is also significant to the design of handoff tools. Our findings indicated that clinicians included content that is comprehensive of the patient's CTICU length of stay (e.g., admission information through short and long-term care plans) on their handoff artifacts. Other studies cite that clinicians only want content that is pertinent to the next shift [37]; therefore, future analysis should look at the scope of data content for the patient's stay to include in handoff tools.

Looking Toward Other Settings

The data presented in this chapter were from an analysis of one CTICU. There are some differences and some similarities among ICUs. We believe the methods used to collect and analyze the data lend confidence to the discussed themes and conclusions drawn from this study. For example, purposive sampling, data saturation (i.e., no new content and structure themes were identified), and triangulation of data for the artifact analysis increase the generalizability of the findings within the CTICU. Analyzing the types of information included on handoff artifacts across ICU settings and clinician types will help us to understand and define the core type of ICU handoff information that should comprise a patient-centered handoff tool and the information that is appropriate for tailored handoffs in specialty care settings.

A Treasure Map of Complexity, Common Ground, and Implications to Informatics

Effective handoff communication requires clinicians to maintain continuity of care by conveying and documenting intermediate (daily) goals and tasks that are aligned with the intra- and interdisciplinary plan of care [28]. Nurses' and physicians' handoff artifacts in the CTICU were highly structured and allowed for annotations and note taking during handoff and patient care activities. Our artifact analysis indicated that the clinicians used these documentation tools to support individual cognitive process as well as communication and collaboration within a discipline. These types of functionalities help trace how individual cognitive processes are related to the flow of information within a system – they serve as a treasure map to piece together and navigate the complexities and common ground that exists within the ICU. Handoff tools remained siloed between disciplines, yet, there was a high degree of overlap in content between the information contained in the nurses' and physicians' handoff artifacts which is evident of established common ground. Yet, consistent with the Interdisciplinary Handoff Information Coding framework, the level of granularity used to capture clinical concepts differed between nurses and physicians for some types of data. The handoff artifacts were semi-structured and contained consistent types of specialty specific information. Due to the observational nature of the study, we could not conclude if the artifact structure was optimal for handoff. However, our compilation of CTICU handoff data elements based on our artifact analysis indicates that the future development and evaluation of semi-structured patient-centered handoff tools with discipline specific views customized for specialty settings may support handoff communication and patient safety. Future work to design computer-based handoff tools integrated with the EHR in a highly specialized critical care setting needs to include an in-depth analysis of the use of paper and computer-based artifacts among different disciplines and clinicians with variable clinical experience. Computer-based handoff tools that are customized to the clinical setting and enable the sharing of interdisciplinary data may support the cognitive work of individuals and the communication of critical patient-centered data.

Discussion Questions

1. How can the concept of content overlap be used to design handoff tools that support best clinical practices?
2. How can we investigate the ideal balance of content that overlaps between disciplines and content that is discipline-specific in handoff tools?
3. How can content overlap be used to increase our understanding of the level of complexity in patient handoffs?

4. How could artifact analysis and content overlap be used to measure common ground between clinicians during patient handoff?
5. Could the concepts of content overlap and common ground be used to develop a standardized measure of complexity in patient handoffs? If so, how?

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