8-1-2016

What Causes Care Coordination Problems? A Case for Microanalysis

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Recommended Citation

Zachary, Wayne; Maulitz, Russell Charles; and Zachary, Drew A. (2016) "What Causes Care Coordination Problems? A Case for Microanalysis," *eGEMs (Generating Evidence & Methods to improve patient outcomes)*: Vol. 4: Iss. 3, Article 3.
DOI: http://dx.doi.org/10.13063/2327-9214.1230
Available at: http://repository.edm-forum.org/egems/vol4/iss3/3

The Electronic Data Methods (EDM) Forum is supported by the Agency for Healthcare Research and Quality (AHRQ), Grant 1U18HS022789-01. eGEMs publications do not reflect the official views of AHRQ or the United States Department of Health and Human Services.

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Abstract

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Coordination Process Diagramming: Coordination Process Diagramming (CPD) is a new framework for representing and analyzing CC arcs at the micro level, separating an arc into its participants and roles, communication structure, organizational structures, and transitions of care, all on a common time line.

Conclusion: Comparative CPD analysis across a sample of CC arcs identifies common CC problems and potential root causes, showing the potential value of the framework. The analyses also suggest intervention strategies that could be applied to attack the root causes of CC problems, including organizational changes, education and training, and additional health information technology development.

Acknowledgements

The research reported in this publication was supported by the National Institute on Aging of the National Institutes of Health, under award number 1R43AG044891. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. We gratefully acknowledge and thank Chioma Onyekwelu, Elissa Iverson, Zachary Risler, and Lauren Zenel who collected and compiled the field data on care coordination communication in the preceding studies and who contributed to the categorization structure that later came to be used in the CPCT. We also acknowledge and thank Susanna Evans, Stephen Zinn, Mark Weiner, and Edgar Chou who contributed narratives of the detailed CC arcs used in the analyses reported here.

Keywords

Informatics, Quality Improvement, Health Care Operations

Disciplines

Health Information Technology | Health Services Research | Other Medicine and Health Sciences

eGEMs
Generating Evidence & Methods to improve patient outcomes

What Causes Care Coordination Problems? A Case for Microanalysis

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ABSTRACT

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Introduction

Care coordination (CC) is an important lever for pursuing a range of health care goals, including improving outcomes, achieving systemic financial sustainability and reducing medical errors. Policy-level efforts to eliminate medical errors,[1,2] manage chronic illness in an aging population,[3] and increase the cost effectiveness of care[4,5] have all focused at least in part on CC. However, the ways in which research and policies have measured and described CC have generally not been based on a data-grounded, empirical understanding of CC. Instead, CC is typically discussed in terms of outcomes and metrics that refer to averages or changes in averages (e.g., the metric of 30-day readmission rates).[6,7] We assert that the basic unit of CC is the individual episode or "arc" of coordination, in which multiple clinicians coordinate their data gathering, treatment, analysis, and communications to address a specific problem presented by a specific patient. Analysis of CC arcs' internal structure and content details is critical for developing empirical theories and models that explain and ultimately predict why specific arcs are understood as being of higher or lower quality, and for bridging the micro- and macro levels to address system-level CC problems. We call this "microanalysis" of CC.

The current trend in CC is to analyze aggregates of CC arcs, using measures or descriptors of CC such as average costs, differences in admission rates, and readmission rates.[6,8,9] This approach can be termed "macroanalysis." The current focus has been on CC macroanalysis because the fine-grained data needed for microanalysis have not been available or easily collected. The growth of electronic health records (EHRs) has at least partially solved this problem, although as discussed below the limited degree of information exchange and interoperability of EHR systems leaves some problems still to be resolved. While macroanalysis can provide a high-level way to quantify CC across time or care-delivery settings, we argue that the macroanalysis approach is not leading us down a productive path to deep understanding of CC. For example, measuring the presence and absence of readmission in a set interval of time can differentiate arcs that meet or fail the criterion. However, the unavailability of any internal (i.e., microanalytical) features of the arc makes it impossible to analyze *why* any specific case meets or fails the criterion. We argue that a microanalysis approach would complement macro-level assessment by providing a way to look inside arcs and would allow us to do the following:

- Understand specific failings, successes, features, and patterns of CC;
- Analytically identify best practices and root causes of problems; and
- Envision solution strategies and improvement opportunities at the arc level.

Today, there is neither a foundational vocabulary of concepts for framing CC microanalysis, or a set of methods and notation that could form the basic building blocks of CC microanalysis. This paper offers such a foundation and an analysis method—called "Coordination Process Diagramming" (CPD)—and discusses some of the benefits that CPD could offer health services and health systems research.

Coordination Process Diagramming

CPD was developed from empirical research[10] using grounded theory methods[11] to collect detailed data on empirical CC arcs. The analysis of those data (discussed further, below) used constructs from social science and information science to guide the analysis of these empirical data and to develop the CPD framework. Specifically, constructs and concepts were drawn and adapted to this domain from social network theory and social network analysis methods;[12,13] and organizational theory—particularly relational coordination theory.[14,15]

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From information science and systems, CPD adapts the long and productive traditions of formal methods for analytical decomposition and diagrammatic representation of systems,[16] particularly from Data Flow Diagramming[17] and the Unified Modeling Language.[18]

These borrowed constructs were used to create abstractions, concepts, and terms that CPD uses to abstractly describe the specific events and processes observed empirically, or that arose during in-depth interviews with clinical participants who were discussing specific (anonymized) CC arcs.

The premise of CC microanalysis is that when examined closely, each CC arc emerges as a complex but unique network of communications between and among many providers, over substantial periods, crossing and recrossing many organizational boundaries. Each arc has a complex but coherent structure, although the conventional way of describing an arc in narrative format tends to obscure the structure of the arc. This is because the linear nature of narrative makes it hard to clearly express the interrelationships among the multiple components involved, such as the different organizations involved at different points in time and the existence of parallel threads of communications unfolding simultaneously.

Press[19] recently offered a novel way to deal with these narrative limitations—animation. He describes and analyzes a specific, complex, and protracted CC arc, using a network diagram to map out all the communications in an 80-day episode. This method on its own is not new, as network diagrams have been used before as means to represent clinical communications.[20,21,22] In the diagram, clinicians are depicted as circles or dots, and communications are depicted as lines connecting the two or more individuals involved. However, because the same individuals communicate multiple times in the CC arc, Press saw that each needed to be represented *separately*. This yielded a complete but visually very complex diagram that still lacked any representation of time. To solve this problem, a graphical animation was added in the online publication. It started out with the primary care provider (PCP), and added each individual communication as a separate line as the overall arc unfolded. Each individual communication is added to the picture as time goes by, with new participants being added as they become involved. As the animation proceeds, the observer can perceive that some dyads have many communications over time, while others have few. The observer can also see how the focus of activity and the participants change over time, analogous to what can be seen in a time-lapse depiction of a construction project. This animation was a powerful scientific visualization for understanding that CC arcs unfold over time and that there is a temporal flow and rich communication structure to the arc. In the end, though, it could not be an effective analytical tool because all of its information is never presented in a single symbolic, explicit representation that explicitly shows how the individual communications are interrelated along a temporal dimension, in a way that allows them to be formally analyzed. In other words, the animation provides a visual, but not an analytical, representation of a CC arc. This example does, however, point out two core building blocks in CPD—the *network structure* and need for *representation of time*.

CPD breaks down a CC arc into a network of relationships through which individual communications flow. This arc network is depicted visually as a social network graph in which individuals are represented as points called "nodes" and communication relationships are depicted as lines between nodes, called "links." Social network analysis is a large field and has a long history (see Wasserman & Faust[23] and Borgati, Mehra, Brass, &

Labianca[24]) that includes applications to health care (see Valente[25]) but it has persistently focused on the structure of networks rather than the processes that occur within those networks.

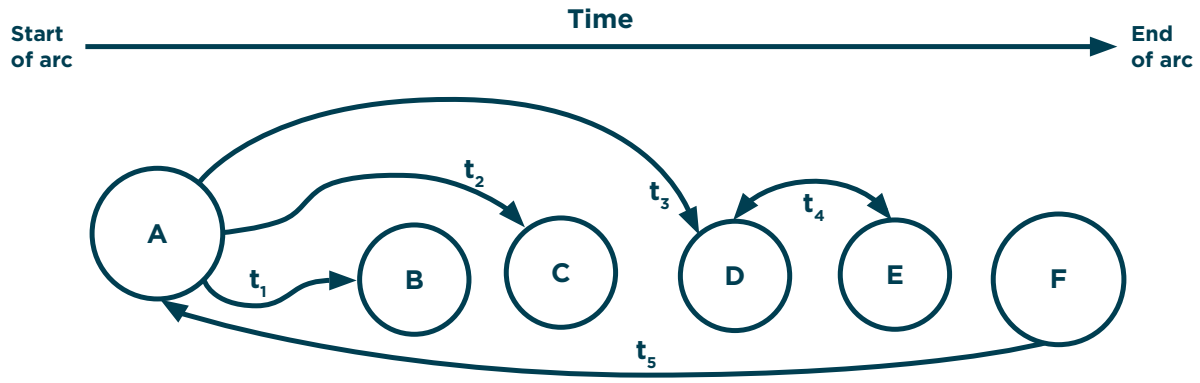
Because CPD is concerned with CC as a process, it uses a unique way of depicting a CC arc as a network, called the "coordination arc diagram." This diagram shows all the nodes involved in the arc, but places them in a specific order along the main axis (i.e., horizontal or vertical) according to the sequence in which they become involved in the arc. Each communication between a pair of nodes is shown as a link between the two nodes involved, with a time annotation indicating the sequence number of that communication in the overall arc. A link in a coordination arc diagram can represent a one-way communication (a "directed link," depicted as an arrow from A to B), or a two-way communication in which there is an interactive exchange of information (a "bidirectional link," depicted by a two-headed arrow between A and B).

A third type found frequently in our data is the "failed link," shown as a directed link with a dashed line. This represents situations in which one clinician attempts to communicate with another, but is unable to do so. Failed communications can be repeatedly retried (leading to delays of needed coordination), or can lead to workaround strategies by which the initiating node tries a different communication path. In both cases, failed communications can result in problems in the process and in undesired outcomes.

Figure 1 shows a very basic coordination arc diagram, depicting a hypothetical CC arc. The arc starts with Dr. A communicating with Dr. B, and gradually involving, in order, clinicians C, D, E, and F. The order in which they join the arc is shown on the horizontal axis, which throughout this paper is shown as the order-of-entry axis. Time in this figure is shown only ordinally (i.e., in terms of the order in which events occur), via the subscripts on each "t" in the diagram—e.g., t_1 is the first communication, t_2 is the second, and so on. If two nodes communicate multiple times, there will be multiple links connecting them, each with a different time annotation.

There are still several aspects of empirical CC arcs that are missing in Figure 1. One, of course, is the content of the communications, which we discuss below. The other factors are represented in the secondary axis of the coordination arc diagram. Since the time axis is shown vertically here, the secondary axis will always be vertical.

Figure 1. Notional Coordination Arc Diagram



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Relevant Organizational Boundaries

The first aspect of structure shown in this second axis is that of clinical organizations. We define "organization" loosely—leaving it to the analyst to define these boundaries—but note two ways in which organizational boundaries become important in CC. One is the diversity of EHR systems. In most if not all of the United States, there are multiple EHR products, produced by different vendors, which for the most part do not transparently share information.[26] When the two organizations involved in an arc do not share an EHR, the organizational boundary presents a barrier for access to patient information for the communicating clinicians. This can be true even when the clinicians belong to the same health care system, for example, when the ambulatory care side of the system uses one EHR and the in-patient care side uses a different EHR. From the CPD perspective, if two clinicians belong to different organizations that do not share an EHR—making electronic sharing of patient data between them difficult or impossible—then those organizational boundaries should be included in the coordination arc diagram.

Another way organizational boundaries affect CC is through the participation, or nonparticipation, in different payer systems (i.e., insurers and coverage plans). Our data showed that patients often make decisions about which provider to choose based on whether or not that payer's organization will accept reimbursement from the patient's payer or plan (if not, the cost may become fully out-of-pocket). In CC arcs, this is seen when a clinician recommends a specific provider (A) for specialty or follow-up care, but the patient chooses another provider (B) because the patient's payer would cover care provided by B but not A.

Relevant organizational boundaries are represented as layers in the secondary axis of a coordination arc diagram. All nodes in the arc that belong in a given organization are placed in the same layer, which is separated from other layers in the diagram by dashed lines. The organizational name is shown in the originating end of the main axis, here, the far left side of the diagram. The clinician who initiates the arc, and all other providers in that organization, are placed in the first clinical layer of the diagram. When a new clinician belonging to a different organization enters the process, a new layer is created below the initiating clinician's organizational layer. When another clinician from another organization becomes part of the arc then another organizational layer is created below that second layer, and so on. These layers make clear where organizationally each participant in the CC arc resides, and their order along the secondary axis shows the order in which their organizations became involved in the arc.

Patient, Family, and Community Environment

While many of the communications that make up a CC arc are between various types of clinicians, the patient and parts of the patient's social environment are often important participants in the CC process. These family and community environments are also loosely defined so that they can be included in the analysis of a specific arc as needed. Certainly for patients that are unable to communicate during parts of an arc, the spouse or other family member can be a crucial source of medical or social history information. We also found in our empirical case sample that clinicians may communicate with patients or family members *to find out what transpired with another clinician*, when that clinician fails to report back directly (see detailed example below). Household members, support groups, or community outreach groups can similarly become part of a CC arc, particularly around times of transition of care.

In a coordination arc diagram, these patient, family, and community-member nodes will be placed in a special layer labeled "patient side." This layer is placed above the top-most clinical organizational layer on the secondary (here, vertical) axis. This top-most layer separates all the nonclinical nodes and communications from those that involve the patient or the patient's network. In this layer, as in all others, the nodes are placed on the primary axis in the order in which they become involved.

A basic coordination arc diagram arc then consists of a coordination process diagram showing all the nodes involved, with the nodes ordered in the main axis according to the sequence in which they become involved in the arc. Each communication between nodes is shown as a directed link with a time annotation indicating the sequence number of that communication in the overall arc. The nodes are further grouped in the secondary axis into layers representing the organization to which they belong, with the patient and patient-related nonclinical nodes occupying the first layer on the secondary access. There is also an optional separate table that defines the chronological time at which each communication occurred. These chronological times can be either absolute (i.e., tied to calendar and clock times) or relative (e.g., to the time of the first communication).

Transitions of Care

Our empirical data show that CC problems are associated with transitions of care from one care setting to another, e.g., in-patient to ambulatory care. Other research[7,9,27] suggests that CC problems increase around these transitions. In fact, an oft-stated policy goal for CC is to minimize the number of transitions of care (e.g., minimizing hospital readmissions within 30 days of discharge). In general, longer CC arcs are more likely to include one or even several such transitions, so it is important to include these in the diagram of the arc. This is done with a specific symbol and with one additional layer in the diagram. The layer is the transitions of care layer, and is represented as the bottom layer on the secondary axis. The layer is labeled "TOCs" for "transitions of care." The symbol is a jagged vertical line with annotations on each side indicating the ending and starting state of the patient. The symbol is placed along the primary axis at the point in the sequence that corresponds to the transition. The states on either side are simple descriptors, such as "ambulatory care," or location (e.g., "hospital A," "rehabilitation/nursing facility B," or "hospice C"). A time annotation, in the same form used for links, can be placed on the transition to situate it precisely in the temporal sequence of the arc.

Start and End Points of the Arc

Many if not most arcs have a well-defined beginning point, involving an initiating complaint. For some, it may be difficult to pinpoint a precise beginning and to distinguish CC arcs, as new problems may arise before earlier initiating problems are resolved. Patients with chronic illness, for example, may proceed through a series of arcs over time. Ending points can be even more difficult to identify. In most cases, the identifiable ending condition may be simply that of no further communications as the patient recovers and treatment ceases. In some cases the outcome will be the patient's death, and in some cases the arc may have to be assigned an arbitrary end, as a new problem or complaint arises that effectively ends one arc and begins another.

To accommodate this range of possibilities, CPD allows optional originating and ending points to be specified for an arc. The originating point (pictured as a diamond with an arrow leading the source of the initial communication link in the arc) can include an event such as test result or new complaint as the initiating point for the arc. Its implicit time

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annotation is t_0. The ending point (pictured as a final link from the recipient of the last communication link to a diamond) can include a range of options. A terminating condition could be defined by "no further communications on the arc after 30 days," or "released to home care for primary care follow-up." It can also refer to a terminating condition (such as transition to hospice care or patient death) or event (such as patient moved out of state).

Indirect (EHR-Mediated) Communications

Most EHR systems allow clinicians to communicate indirectly by placing notes or requests to other clinicians within their organization. These indirect communications may involve a substantial latency between the time the note is created and the time it is received. In our empirical data we have seen cases in which the note is either never retrieved and read or this happens only at a time too late to be meaningful. CPD breaks this link into two parts—the first part in which the initiating person creates the EHR note (denoted as a link from the node to an EHR symbol, annotated by the initiating time), and the second part in which the recipient actually receives it (denoted by a separate link from the EHR symbol to the recipient, annotated by the time of actual retrieval). This also allows for some indirect communications to become de facto failed communications.

In summary, the basic coordination arc diagram decomposes and visually represents a CC arc in terms of five types of components:

- participants—the persons involved the arc and the role of each, including the patient and key nonclinicians such as the patient's family;
- Communications—who communicates with whom;
- Time when the communication occurs, in relative terms;
- Organizations to which each clinical participant belongs; and
- Transitions of care—movement of the patient from one form or location of care to another.

Table 1 summarizes the graphical notation used in a coordination process diagram.

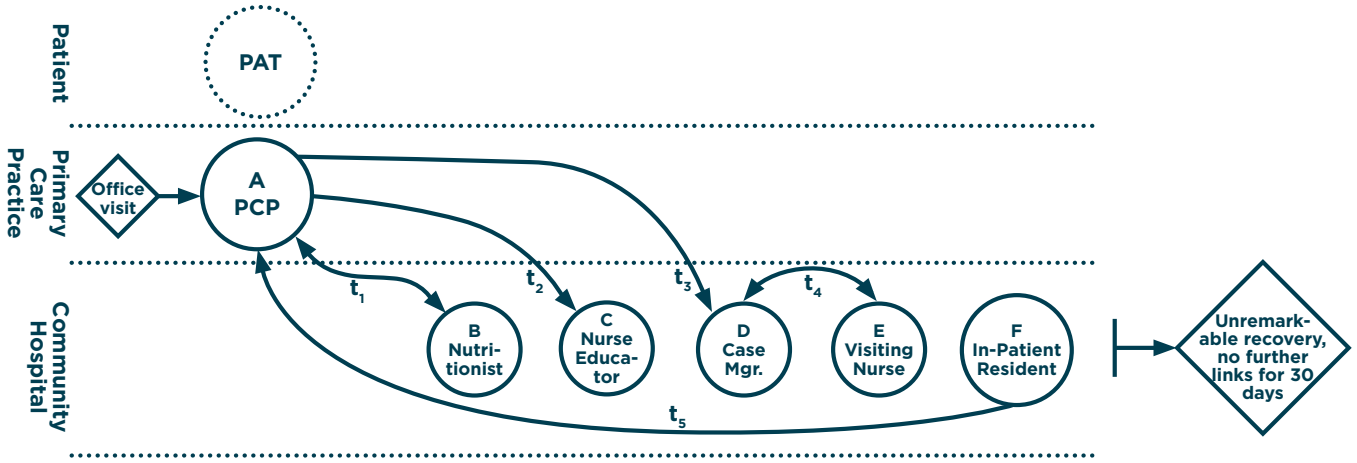
Figure 2 shows a coordination arc diagram of the case narrative given immediately below. All the CPDs included here were created with general-purpose, commercial drawing tools (in this case Microsoft PowerPoint). Templates for CPD primitives (i.e., those in Table 1) can be easily created in general-purpose commercial drawing tools (such as Microsoft's PowerPoint or Visio or Omni Group's OmniGraffle) to support CPD creation and editing.

Mr. X, a 77-year-old male with a past medical history of hypertension and obesity, now presenting with new onset left lower leg pain, sees Dr. A. The patient reports having low leg pain for the past two weeks. He reports having driven on a long auto trip two weeks previously, and noticing the swelling shortly afterward. He denies chest pain and shortness of breath. After his PCP, Dr. A, sees Mr. X in Dr. A's primary care office, Dr. A admits him to Community Hospital A. There, Dr. A requests a duplex ultrasound of his left leg, which proves positive for deep vein thrombosis. Dr. A then starts Mr. X on anticoagulation (Lovenox and Coumadin) after EHR confirmation of a prior negative colonoscopy report. On day 2, Dr. A, on rounds, discusses the following: with nutritionist B he discusses diet related to Coumadin use; with nurse C he discusses educating the patient on home Lovenox injections, and with case manager D he discusses obtaining prior authorization for the patient to receive home Lovenox injections, as well as to have a visiting nurse E scheduled to see the patient to ensure proper delivery of the injections. At discharge, the inpatient resident F taking care of Mr. X communicates with Dr. A, providing details of the Coumadin dosing: Coumadin 5 mg daily, with home Lovenox injections subcutaneously 100

Table 1. Coordination Process Diagram Notation

TERM	MEANING	SYMBOL
Node (person)	A person in the care coordination process	
Node (data)	Data repository (e.g., EHR) in the CC process	
Link (directed)	One-way communication event	
Link (bidirectional)	Two-way communication event	
Link (failed)	Failed communication attempt	
Time (ordinal)	Time annotation for link	t_i
Task note in	Node puts asynchronous task into EHR	
Task note out	Node retrieves asynchronous task from EHR	
Organization	Brackets bounding nodes belonging in organization "name"	name
Transition of care	Patient transitions from care state/location to care state/location B	A B
Arc start	Originating event for care coordination arc	
Arc ends	Terminating event or criterions for care coordination arc	

Figure 2. Complete Coordination Process Diagram Example



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mg twice daily. The patient is discharged to home care, receiving the scheduled monitoring to assess adequacy of anticoagulation.

The CC is simple and effective in this arc. The PCP is able to communicate with all the desired parties in a timely manner, all the coordinated care is provided as planned, there are no unexpected complication or events, and the patient recovers as intended.

Representing Content Within the Arc

The coordination arc diagram offers a readable visualization of the sequence of communications among people involved in a CC arc, that also identifies the organizations involved and the transitions of care that occur, along the initiating event and outcome. However by itself it is only like a table of contents for the substance of the arc, which lies in the details of the individual communications represented by the links in the diagram. A CC arc cannot be fully analyzed until the content of the individual communications is also explicitly represented. This is done through the Communication Process Content Table (CPCT), which accompanies a coordination process diagram. In the CPCT, each link (completed and failed) is represented by an extended list of information, grouped into four types of information:

1. Description of the link itself;
2. Description of the characteristics of the communication event that occurs across that link;
3. Patient information that is the context of the communication is specified; and
4. Semantic content of the communication.

Each is defined further, below. The specific methods for categorizing or coding content below were developed in the grounded research on which this work is based.[10]

Link Information

The entry in the CPCT for a link begins with the sequence number of the link, for example with "6" for the link noted as t_6 in the diagram. A specific time for the communication relative to the start of the arc can also be given (using whatever system the analyst wants, as long as it is well-defined and consistently used through the CPCT). The link is then defined by its type in the coordination arc diagram—directed, bidirectional, or failed.

The link participants are denoted using terminology from communication network theory, in which the node that initiates a communication is termed the "source," and the nodes to which the information is directed are termed the "sinks." The source node designator (e.g., A, B, etc.) from the coordination process diagram is used to label the source and sink for each node. Each participant is also coded according to a clinical role. These roles are included because they constrain the health service functions that the nodes provide, and the kinds of information that may be relevant to each node. Including them also provides a means to explore the effect of roles and communications on outcomes, for example whether the degree of involvement of the PCP in downstream communications has an effect on outcomes (as suggested by Stiles et al.[28]).

Characteristics of the Communication

These are noncontent aspects of the communication, and include the modality of the communication and the purpose that the source had in initiating the communication. The content of the communication is typically constrained by a specific functional intent. Our empirical studies of CC communications found that nearly all were made with one (or occasionally several) of eight purposes:

1. Discussing *cross-coverage* within a practice;
2. *Cross-eliciting* of thoughts from a colleague of similar role;

3. *Drill-down eliciting* of thoughts from a colleague with a relevant specialty;
4. Attempting to achieve *situational convergence* among two or more clinicians participating in the arc but from different perspectives;
5. Communicating an *alert of a state change* of the patient;
6. Affecting a *handoff* across shifts or locations;
7. Providing instruction and evaluation feedback (typically to a resident or student); and
8. Attempting to *report back* the results of a test, study, or procedure.

Finally, the link is described in terms of the *modality* or medium by which the communication occurred, e.g., face-to-face contact, telephone, email, text message, chat, pager, or via EHR task note.

Patient Context

Most CC communications include explicit patient information as context for the specific question, request, report, or discussion that is the main substance of the communication. The CPCT is used to capture the following context elements, as they may apply to the specific communication:

- Problem list items, medications, planned or completed studies, and results;
- Name or identifier of the patient's PCP or attending physician;
- Patient social context, e.g., residence status and availability of social support; and
- Patient gender, age, and insurance status—although also including race, ethnicity, and gender identity can allow health disparities to be analyzed.

The CPCT also summarizes the "semantic content" of the communication, in free text for a directed link, or as a set of transactions summarizing the communications from each party.

The overall form of the CPCT is a table in which each column represents a specific link in the coordination process diagram. The order of the links reflects the temporal order of the communication in the overall process. Each row is used to record information of each type in each category described above. This layout allows an easy inspection of, for example, how important patient context information is appropriately propagated over time, or gets lost—resulting, for example, in duplicative testing.

We note that if the organization of each clinician is added and if the TOCs are noted in a separate table, then *all* the information in the diagram is contained in the CPCT. This is important because it makes the full CC arc amenable to computational analysis by the increasingly powerful tools for analysis of social network data, such as ORA Netscenes,[29] though such analyses are not further discussed here.

Appendix A shows a detailed example of a moderately complex CC arc, beginning with a narrative presentation, followed by a coordination process diagram and a full CPCT.

A Note on Data

The research that provides the grounding for this method included two data sets: a set of 12 detailed narrative analyses of real but anonymized full CC arcs from a set of PCPs in the same practice and a set of 355 individual links captured directly from field shadowing of those same PCPs[30] for one to three (four-hour) work shifts per week, over a period of 12 weeks. The providers of the full arc narratives were asked to describe interesting cases (either problematic or nonproblematic) of their choosing; however, most of the cases were problematic. Each of the full CC arc narratives was modeled using CPD, at both the coordination process diagram and the CPCT levels. In all discussion of the arc narratives

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here, feminine pronouns are used to describe all providers, to further preserve anonymity. The large sample of link data was used to develop and refine the structure of the CPCT. One of the full arcs was used in the example (Figure 2) above without a CPCT, and a second is shown in full detail in the Appendix.

The Value of Microanalysis

The CPD is a synoptic view that shows multiple relationships within a CC arc, while its CPCT adds multiple levels that detail the communication relationships. Like a map, a CPD is meant to be read, analyzed, and used as a problem-solving tool, with its CPCT there for reference when specific details matter, (e.g., were the links t_3 and t_4 minutes, hours, or days apart; and exactly what parts of the patient's case did the parties to those links discuss)? Ultimately, the analysis of CPDs is an interpretive one that depends on the problem at hand, the clinical content of the CC arc, and problem-specific heuristics or guidelines. Understanding the content relies on clinical understanding; the structure of the CPD and the analysis heuristics and guidelines allow it to be applied more precisely and diagnostically.

We used the CPD process to deconstruct and compare microanalyses across the set of 12 empirical arcs discussed above. While one of those (the case in Figure 2) showed no problems in CC, the remaining eleven did contain problems. On the surface, each suboptimal CC arc seemed to fall short in ways that are unique to the characteristics of the case. Yet, when we microanalyzed the arcs comparatively with CPD, clear patterns emerged that allowed us not only to identify consistent communication problems, but also to determine how the CC problems led to suboptimal quality of care or negative outcomes. In doing so, we also created some example heuristics and guidelines that could be used to microanalyze other CC arc CPDs. Four specific problems, and their associated root causes, are discussed below.

Delays in Care

The most common class of problem found (in more than two-thirds of the arcs) was that appropriate care was delayed, often multiple times, during the arc because of the way that care was coordinated. Often the root cause was *failed communications*, with one clinician sometimes trying for days to reach another to obtain needed information. In most cases failed communications were across organizational boundaries that did not share a common or compatible EHR system that would allow the clinician in need to access the information directly.

In many of the cases, the clinician stymied by a failed communication would try to find another way to convey the information or reach the desired clinician. In some cases *indirect communications* worked, such as messages left with answering services that were related in a timely fashion to the desired target. In other cases they resulted in the information reaching a different person, e.g., someone covering the intended recipient, who then may or may not have relayed the information in a timely fashion or done so without at least partially confusing it or omitting elements.

Example Heuristic: Look for failed communication links and "workaround" communication processes in the CPD. If and when found, evaluate (via the CPCT) the length of delay caused against the patients care needs to determine if needed care was substantively delayed by this.

Another common root cause of delays in care was that of *missing communications*—those that arguably should have occurred (or at least been attempted) but did not. In our cases, these universally occurred across organizational boundaries, either between specialists and PCPs,

or between members of the inpatient team and the patient's PCP or relevant specialist. Identifying missing communications is a unique product of microanalysis, because only by examining both the structure and the substance of the internal details of an arc can one see where communication would have been expected and appropriate, and would affect the course of the arc.

Example Heuristic: Review treatment and care provided in the arcs' CPD and CPCT in terms of what was known to the PCP or by other earlier participants in the arc. Examine CPCT to see if existing tests, conditions, or result were not sought via communications, and instead were unnecessarily redone. Evaluate against patient's care needs to determine if needed care was substantively delayed by this.

Another common cause of delays in care was the *incomplete or inadequate propagation of patient context information* forward in the arc. Prior tests, diagnoses, or findings were sometimes not communicated down the arc, resulting in delayed care while the tests or analyses were redone (this result is also discussed below under unnecessary procedures). This issue arose when the arc had crossed an organizational boundary and the current clinicians did not have access to the EHR in which such history data would have been recorded. At the same time, the clinician could and arguably should have attempted to communicate directly with the patient's PCP to gather such data. Thus there were two ways to avoid this problem, but neither was used. Incomplete propagation of context also occurred when very terse communications (e.g., with text or pager messages, or short emails) were used to hand off or inform a down-arc clinician that the patient would be presenting shortly with an expectation that a follow-up phone call (which ultimately did not occur) would be used to communicate the relevant context and history.

Finally, there were a few cases in which care was *delayed by payer*. For example, in one case, a patient attempted to change his PCP after release from a hospitalization, only to find that the insurance provider tied payment to a specific PCP and required paperwork (and a delay) before that PCP could be changed. Examples like this suggest that payer policies become part of the CC landscape and affect outcomes, whether or not they are recognized or intended as such.

Unnecessary Tests and Procedures (and Attendant Unnecessary Costs)

Not surprisingly, the microanalyses showed that this class of problems had root causes similar to those of problems in delayed care. There were multiple instances in which information on the patient's history was lacking, leading to duplicative tests and procedures. As with delayed care, the information was sometimes lacking because of failed communications, inadequate hand-off communications, and information-seeking communications that should have occurred but didn't. The barriers posed by incompatible EHR systems across organizational barriers represent contributing root causes in all of these cases.

We also observed some instances in which errors and miscommunications led to unnecessary testing. These were cases where test orders were misentered, lost, or garbled (on either the ordering side or the testing side) so that the wrong test was done or the test was done with improper instructions, and as a result the patient had to undergo another test. (This also contributed to delays in necessary care.)

Example Heuristic: Review diagnostic tests and procedures provided in the arc's CPD in terms of what was known to the PCP or by other earlier participants in the arc. Examine the CPCT to see if the tests or procedures had been done previously,

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but their existence and results were not sought downstream in the arc so they were unnecessarily redone. Identify these as being unnecessary tests and procedures, and therefore creating unnecessary costs.

A subtler, and perhaps more disturbing, root cause of unnecessary care was *disregard of communications* combined with *preemptive actions* by some clinicians. In one case, for example, clinicians with different relevant specialties were asked to consult on a problem. The others recommended watchful waiting, but a surgeon recommended immediate amputation of an ischemic toe and proceeded to schedule the procedure and perform it, without communicating that decision with the others in the arc, including the PCP. In this case, each clinician was in a different organization from the PCP and from each other clinician in the arc at that point, and these boundaries (and their associated EHR noncompatibilities) made such preemptive actions easier to take. Cases such as this ultimately highlight the fact that CC is an ad hoc process, in which no one is explicitly in charge and in which many participants may not understand it to be a cooperative process.

Ineffective Care, Unnecessary Complications

Here, we found two clusters of root causes. The more common was *missing communications*, especially around transitions of care from in-patient to ambulatory care. In some cases, in patient teams formed expectations for the posttransition care to be provided by the PCP office or a home-care team, but did not communicate those expectations or even notify the other providers of the discharge. Another group of cases shows a pattern in which multiple specialists or a specialist and a PCP are each treating a patient for a different problem. In these cases, the clinicians either do not coordinate regarding their care—leading to countervailing or conflicting treatment—or do not adequately communicate the issues to the patient.

Example heuristic: Examine the arc's progression (via the CPD and CPCT) after a TOC to identify any complications. If found, look for links from clinicians on the before-TOC side to the after-TOC side that could have prepared the post-TOC side clinicians to watch for or prevent the complication. If such communication was possible but not found, identify the resulting complication as being unnecessary.

We also found one example in which such *conflicting communications* interacted badly with *automated actions*, in this case at the pharmacy. One clinician told a patient to start a new medication and cancel an existing one, which it was replacing, without communicating this to either the pharmacy or the PCP. When the patient arrived at the pharmacy, the new medication was there along with an automated refill of the to-be-replaced prescription. Confused, the patient took this to mean that both were to be taken, resulting in a complication. Since the PCP hadn't been told about the medication change (a missing communication), the PCP was unclear as to the source of the complication that emerged.

Poor Patient Experiences and Unnecessary Patient Anxiety

As noted earlier, emerging efforts to measure CC on patient experience and perceptions means that the nonclinical effects on the patient must also be considered as outcomes. In many or most of the cases, problems in CC degraded the patient's experience and often caused extreme anxiety.

Example heuristic: If the analysis of the CC arc found the presence of unnecessary tests or unnecessary complications, then identify this as an arc with poor patient experiences.

One interesting finding of the microanalyses was that many clinicians become very resourceful in dealing with CC problems. Many have developed workaround strategies for situations when communications fail, such as finding other ways to reach the intended target, often involving intermediaries. For example, when repeatedly unable to reach the prior PCP of a new patient directly, one clinician engaged the office manager to contact the PCP's office manager directly, in order to access copies of the patient's medical records. Another, dissatisfied with a down-arc specialist's lack of report-back communications on a patient she had sent to him, found that she could use her EHR log in at a third facility where both had privileges, to find and review the test results directly.

On the negative side however, was the fact that communication mechanisms that were not compliant with the Health Insurance Portability and Accountability Act (HIPAA), particularly email and text messages, were very frequently used to communicate patient information that should be protected.

Conclusions

CPD allows the internal details of a CC arc to be described and formalized in a readable visual representation of the structure and flow of the arc (the coordination arc diagram)—in a detailed data representation that captures the content along with the structure of the arc (the CPCT). The detail provided by the CPD decomposition offers the level of information needed to identify why some CC arcs exhibit suboptimal clinical outcomes while others do not, and to identify and make generalizations about the root causes of problems at the arc level. From the patient perspective, recent work[31,32,33] to create measurement scales for patient perceptions of CC arcs could also be combined with microanalysis to help identify common features of arcs that lead to negative patient experiences and perceptions. CC microanalysis provides a needed framework and methodological foundation for developing and assessing remediation strategies for CC problems.

We describe below four strategies for improving or supporting CC practices from comparative CC microanalysis. The first two describe ways in which the CC practices at the individual and organizational levels could be improved with insights from wider CPD-based microanalysis. The last two describe ways in which CPD can support CC documentation and CC research.

Education and Training Informed by CC Microanalysis

Currently, CC is an ad hoc process with no explicit management guidelines or commonly accepted principles of coordination that can be taught and consistently applied. Systematic collection and microanalysis of CC arcs can create an evidence base from which best practices as well as common errors can be identified. These, in turn, can be used to develop more process-focused guidelines and coordination principles that can be incorporated into medical education to train clinicians of all stripes on "what works" and "what doesn't." Direct training in CC microanalysis can also increase clinicians' self-awareness of their own CC practices, which can help to improve coordination across specialties or organizations, and avoid missed communications.

Organizational Changes Informed by CC Microanalysis

Organizational policies and practices, as we have argued here, impede or deter CC, when viewed at the microanalytical level. These impediments include, first and foremost, the barriers created by incompatible EHRs. Here again, the systematic collection and microanalysis of CC arcs can create an evidence base of how these barriers function,

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and can lead to developing organizational solutions to remove those barriers. Potential improvements suggested from the CC microanalyses here include adjusting policies that discourage full CC communication with out-of-organization providers and payer policies that force patients out of the recommended CC flow. We note that such changes require organizational and leadership support, and suggest that empirical microanalysis *data* is the best way to motivate change.

Technological Developments to Support and Automate CC Documentation

While the coordination arc diagram is constructible from narrative descriptions (which clinicians seem readily able to produce), the data in the CPCT can be difficult to collect manually. The tasking-note functionality in many commercial EHRs can capture data on some of the within-EHR communication links (about 50 percent is from data reported in Zachary, Maulitz, Iverson, Onyekwelu, Risler & Zenel[30]). The CPD framework, however, offers a target for the data needed in an analogous electronic CC repository. It also suggests personal information tools as a way to gather the data needed to populate the repository. These tools could be embedded into the smart phones that are already used to generate the phone calls, emails, and text messages that make up so much of empirical CC arcs.

Assessment and Design Cases

A repository of CC arcs in the form of CPDs and CPCT tables can serve as a data resource in CC research on the assessment or simulation analysis of CC interventions. Such a repository can provide baseline cases against which possible inventions or assessment strategies could be tested. Individual CC arcs represented in CPD form can also be used as "use cases" that form the basis for modern design methods for clinical information systems. Unlike narrative descriptions, the CPR representations provide the detail and precision that system designers want and need in the design process.

The microanalysis of CC is an emerging subject with many possible next steps in research, education, and clinical practice. At the practice level there is an immediate opportunity and need to work toward removing the organizational barriers to CC that have been discussed here, and toward removing EHR information exchange barriers that are already a growing concern. At the educational level, there is an opportunity and a need to incorporate a microanalytics view of CC to help future—and present—clinicians become more aware of this view and its benefits to practice. Finally, additional research—and research support—is needed to collect larger bodies of CC data, including comparable data across regions in the United States, and in non-United States health care systems. From the microanalysis of these data, heuristics and guidelines can then be developed to generalize the research reported here to identify problem areas and root causes, as well as to identify best practices. Microanalysis and CPD constructs also afford opportunities for future research to analyze—both manually and via computer simulation—potential organizational and behavioral interventions intended to improve CC.

Acknowledgements

The research reported in this publication was supported by the National Institute on Aging of the National Institutes of Health, under award number 1R43AG044891. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. We gratefully acknowledge and thank Chioma Onyekwelu, Elissa Iverson, Zachary Risler, and Lauren Zenel who collected and compiled the field data on care coordination communication in the preceding studies and who contributed to

the categorization structure that later came to be used in the CPCT. We also acknowledge and thank Susanna Evans, Stephen Zinn, Mark Weiner, and Edgar Chou who contributed narratives of the detailed CC arcs used in the analyses reported here.

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Appendix A: Detailed CPD Example

Ms. X, a 68-year-old Caucasian female with a history of diabetes, hypertension, morbid obesity, and intermittent abdominal pain, presents to Dr. A (PCP) for a recurrence of her pain. She notes it is in the epigastrium (area near stomach) and seems to follow meals. Worrisomely, her rectal exam showed occult blood. The abdominal examination is unremarkable.

She is therefore referred to Dr. B, a colorectal surgeon, for a work-up to include a colonoscopy. Dr. B performs an initial examination and notes "no GI complaints" and "no distension" on physical. Dr. B sets up Ms. X for a colonoscopy, to be performed in the operating room under anesthesia because of the convoluted large intestine. Dr. B sends a task detailing the plan going forward to Dr. C, the head of Dr. B's group. Dr. C then forwards this task to Dr. A to complete the circle and to make Dr. A aware of Ms. X's current status.

Four days later, Ms. X returns to Dr. A, who is ready for the meeting because of the completed background communication. Hearing hyperactive bowel sounds and a continued complaint of abdominal discomfort. Dr. A prescribes hyoscyamine, a drug that when taken by mouth or in sublingual form reduces intestinal motility. Dr. A urges the patient to continue her work-up with Dr. C.

A week to week-and-a-half after these events, the patient presents to the emergency room with worsening pain. Emergency room attending physician Dr. F calls in Dr. B to evaluate the patient, admits her for observation, and orders cardiac clearance from Dr. D, a cardiologist. At this point Dr. A's service is contacted by Dr. B. The respondent is Dr. E, a resident (trainee), on the in-patient team, who sends an EHR task to Dr. A detailing the admission. Dr. A reads it later that day.

Dr. E's tasking note states that "pt X was admitted to University Hospital 4/22-4/23 for abdominal pain/nausea/vomiting and acute cholecystitis, and was discharged after IV fluid rehydration and pain medications." The task goes on to say "Ms. X was recalled and readmitted on 4/24 after both blood cultures [were] positive for gram negative rods."

The patient is now placed on vigorous hydration and antibiotics by the two—primary care and surgery—in-patient teams. As of April 26th, no one from these in-patient teams has contacted Dr. A with an update on Ms. X's status. On this date, Dr. A therefore calls Ms. X's home in hopes of getting updated information from her or her husband. There is no answer. Dr. A leaves a message requesting a return telephone call. An hour later, Mr. X called on behalf of his wife and provided a final update. Though still in the hospital, Mr. X states that his wife is improving on antibiotics after having a colonoscopy that showed diverticulitis. She notes that a biopsy of the involved portion of the colon mucosa is pending for microscopic evidence of malignancy. Dr. A e-mailed Dr. B requesting that she call back to provide timely follow-up, which Dr. B did later that day.

Figure A1 shows the coordination process diagram for this narrative. Table A1 shows the complete Coordination Process Communication Table (CPCT).

Figure A1. Coordination Process Diagram

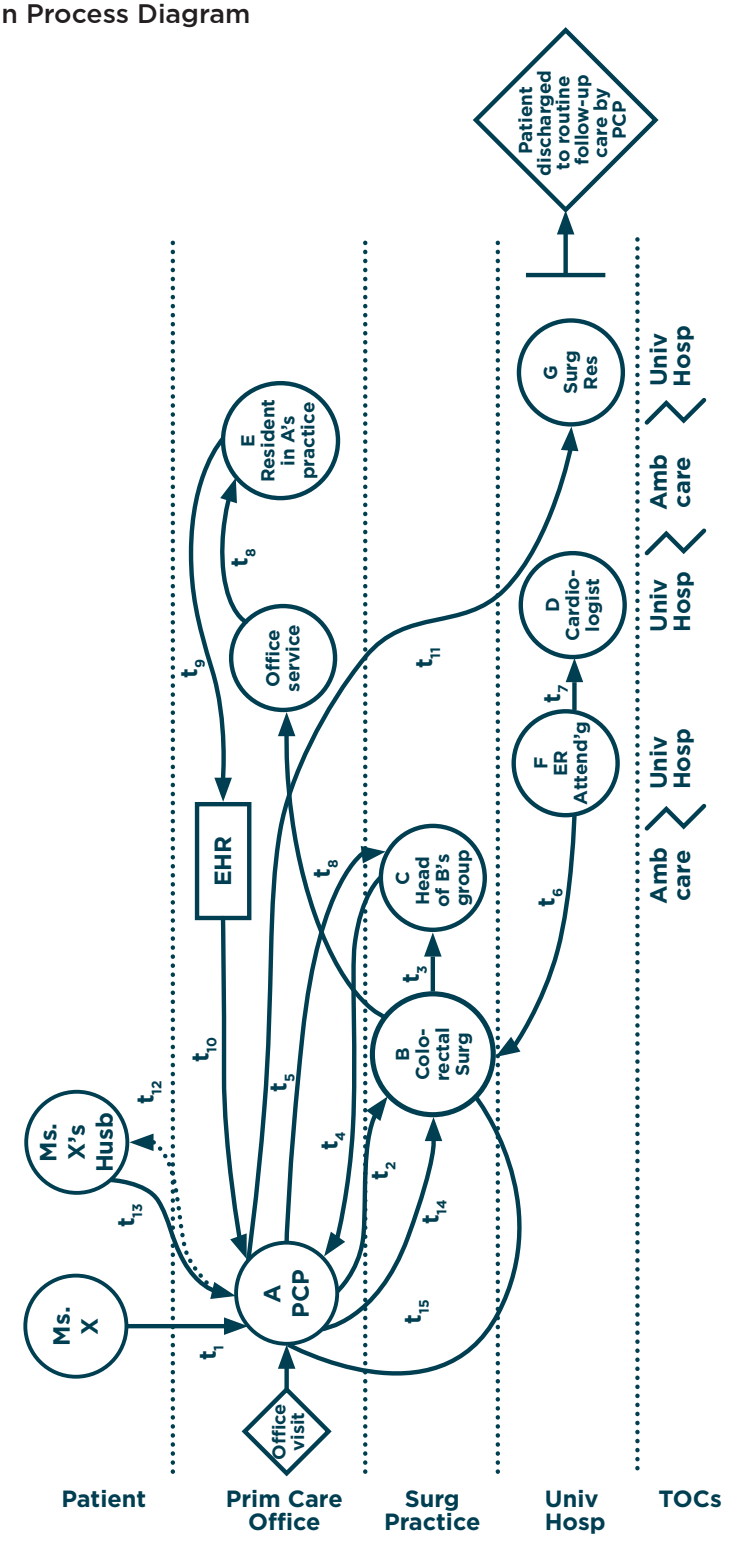

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Table A1. Coordination Process Communication Table

	1	2	3	4	5	6	7
Comm location:	Office	Office	Office	Office	Office	Hospital	Hospital
Time rel to start (days.hrs)	0	1	2	3		15	15
Who-Who	X→A	A→B	B→C	C-A	A→C	F→B	F→D
Intention	present problem	drill-down spec	handoff	report back	report back	cross-elicit	cross-elicit
Modality	face-face	EHR	EHR	EHR	EHR	face-face	phone
PT Gender, age, Insurance	F,68,Medicare	F,68,Medicare	F,68,Medicare	F,68,Medicare	F,68,Medicare	F,68,Medicare	F,68,Medicare
PT Chronic problems	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus
PT Acute problems	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain
PT medications						hyoscyamine	hyoscyamine
Studies/Proc ordered	rectal exam	rectal exam	rectal exam, colonoscopy	rectal exam, colonoscopy			
Studies/Proc results	occult blood	occult blood	occult blood, results pending	occult blood, results pending			
Communication content summary		A sends B an EHR task regarding pt's intermittent abdominal pain and + rectal exam.	B sends C a task to detail pt's plan for colonoscopy.	C forwards A a task with detailed plan for pt.	A forwards C a task with detailed plan for pt.	F consults B to evaluate pt. Sink admits pt to the hospital for observation.	F consults D (cardiologist) for pt to have cardiac clearance while admitted in hospital.

Table A1. Coordination Process Communication Table (Cont'd)

	8	9, 10	11	12	13	14	15
Comm location:	Hospital	Hospital	Hospital	Office	P's home	Office	Office
Time rel to start (days.hrs)	18.1	18.6, 18.14	19	20	20	20	21
Who-Who	B→A's service→E	E→EHR→A	A→G	A→X (failed)	X→A	A→B	B→A
Intention	report back	report back	situation converge	situation converge	report back	info request	situation converge
Modality	pager	EHR	face-face	phone	phone	email	phone
PT Gender, age, Insurance	F,68,Medicare	F,68,Medicare	F,68,Medicare	F,68,Medicare	not discussed	F,68,Medicare	F,68,Medicare
PT Chronic problems	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus	not discussed	Hypertension, Diabetes Mellitus	Hypertension, Diabetes Mellitus
PT Acute problems	morbid obesity, intermittent abdominal pain	morbid obesity, intermittent abdominal pain, acute cholecystitis	morbid obesity, intermittent abdominal pain, acute cholecystitis		not discussed	morbid obesity, intermittent abdominal pain, acute cholecystitis, diverticulitus	morbid obesity, intermittent abdominal pain, acute cholecystitis, diverticulitus
PT medications	hyoscyamine	AB, hyoscyamine, intravenous fluid, pain medication	AB, hyoscyamine, intravenous fluid, pain medication		not discussed	AB, hyoscyamine, intravenous fluid, pain medication	AB, hyoscyamine, intravenous fluid, pain medication
Studies/Proc ordered		CS	CS		not discussed		colonoscopy, colon biopsy
Studies/Proc results		blood cultures positive for gram negative rods	blood cultures positive for gram negative rods		not discussed		diverticulitis, results pending
Communication content summary	B sends page to E (in-patient covering resident for pt's PCP) detailing pt's admission.	EHR note:, *[full note text in narrative above, not here due to space limitations]*	A and G decide to place pt on vigorous hydration and antibiotics for pt's positive blood cultures.		**not discussed**	A sends email to B requesting information about pt's hospital stay.	B calls A to discuss details about pt's admission and inform source that pt would be discharged for follow up care.