Describing and Modeling Workflow and Information Flow in Chronic Disease Care

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Abstract

Objectives: The goal of the study was to develop an in-depth understanding of work practices, workflow, and information flow in chronic disease care, to facilitate development of context-appropriate informatics tools.

Design: The study was conducted over a 10-month period in three ambulatory clinics providing chronic disease care. The authors iteratively collected data using direct observation and semi-structured interviews.

Measurements: The authors observed all aspects of care in three different chronic disease clinics for over 150 hours, including 157 patient-provider interactions. Observation focused on interactions among people, processes, and technology. Observation data were analyzed through an open coding approach. The authors then developed models of workflow and information flow using Hierarchical Task Analysis and Soft Systems Methodology. The authors also conducted nine semi-structured interviews to confirm and refine the models.

Results: The study had three primary outcomes: models of workflow for each clinic, models of information flow for each clinic, and an in-depth description of work practices and the role of health information technology (HIT) in the clinics. The authors identified gaps between the existing HIT functionality and the needs of chronic disease providers.

Conclusions: In response to the analysis of workflow and information flow, the authors developed ten guidelines for design of HIT to support chronic disease care, including recommendations to pursue modular approaches to design that would support disease-specific needs. The study demonstrates the importance of evaluating workflow and information flow in HIT design and implementation.

Introduction

Health information technology (HIT) can enhance efficiency, increase patient safety, and improve patient outcomes. However, features of HIT intended to improve patient care can lead to rejection of HIT, or can produce unexpected negative consequences or unsafe workarounds if poorly aligned with workflow.

More than 90 million people in the United States, or 30% of the population, have chronic diseases. HIT can assist with longitudinal management of chronic disease by, for example, displaying disease status trends and tracking compliance with recommended care guidelines. The translation of theoretical benefits of HIT into actual improvements in chronic disease care has seen only limited success, in part due to insufficient information on how to effectively integrate these tools into existing ambulatory practice.

Researchers have developed rich descriptions of HIT-related workflow in specific inpatient clinical settings such as critical care units, emergency care departments, and general medicine departments. Multiple studies focused on evaluating the impact of specific HIT implementations, such as new workflow-related challenges introduced by computerized provider order entry, potential patient safety compromises caused by implementation of automated drug dispensing systems, changes in workload and communication after implementation of an electronic whiteboard, and a lack of changes in work routines after implementation of electronic medical records. A few open-ended workflow studies have also been conducted, not linked to evaluation of specific HIT-implmentations.

Several researchers have examined workflow in outpatient care environments, most frequently focused on primary care settings and on specific processes such as immunization delivery in primary care, diagnostic testing processes, and prescribing practices. The limited number of outpatient workflow studies focused on chronic disease care have...
typically been set in a single chronic disease domain, such as examining a registry used to organize diabetes mellitus care, developing HIT to deliver patient-centric coordination of multiple sclerosis care across multiple providers, and refining web-based systems to support delivery of home nursing care to patients with congestive heart failure. Previous chronic disease care workflow studies have led to an understanding of the workflow and information flow of providers and patients in specific contexts and have supported development of domain-specific HIT. Our research approach sought to broaden the scope of existing outpatient workflow research, by examining multiple specialty care environments in an open-ended fashion and by determining commonalities and differences among these environments.

The study’s goal was to evaluate and compare provider workflow and information flow across three chronic disease domains in the ambulatory care environment. We studied the interaction between clinical workflow and an established electronic health record (EHR) in these clinics to learn about delivery processes and provider needs. We previously demonstrated the feasibility of our methods in a pilot study in a multiple sclerosis (MS) clinic. The present paper extends the pilot study to two additional chronic disease clinics, cystic fibrosis (CF) and diabetes mellitus (DM), discusses the process we used to develop models of workflow and information flow in each of the three clinics, and provides guidance on the unique informatics needs of the chronic disease care environment. The three clinics were part of the same Academic Medical Center and had access to the same HIT resources, but differed in the chronic disease treated, the specifics of care provided, the number of patients managed, and the number and type of providers. The research questions motivating the study were: what are the similarities and differences in workflow and information flow during management of different chronic diseases? How do these similarities and differences impact the design and implementation of HIT applications?

**Methods**

**Study Design**

Data were collected and analyzed iteratively over a 10-month period using direct observation, semi-structured interviews, analysis of artifacts, and development of workflow and information flow models (Figure 1, available as an online data supplement at [http://www.jamia.org](http://www.jamia.org)). Data collection and analysis continued until data saturation, when additional data did not change analytic results. Vanderbilt University’s Institutional Review Board (IRB) approved study procedures before data collection.

The study design focused on the use of technology in complex and dynamic care environments from the perspective of the study subjects. A pilot study set in a single clinic confirmed the need for direct observation but also suggested the need to incorporate semi-structured interviews to fill in details and confirm findings. Data from the pilot study were merged into the full study.

**Clinic Selection**

The study team considered fifteen chronic disease care clinics at Vanderbilt University Medical Center (VUMC) for inclusion. A researcher (KMU) conducted open-ended interviews with key informants from nine clinics to gather preliminary contextual data. We then evaluated each clinic’s ability to meet study goals using the Strengths, Weaknesses, Opportunities, Threats (SWOT) framework. Examples of strengths and weaknesses included clinic accessibility, existing use of technology, and organizational structure. Examples of opportunities and threats included trends in care, existing informatics projects, and departmental policies. We used the SWOT process to select sites with the highest ratings in terms of strengths and opportunities and with manageable weaknesses and threats. The SWOT process also assisted the research team with developing strategies to ameliorate potential study barriers at the sites before beginning data collection. The researchers selected three adult subspecialty clinics for the study based on the SWOT analysis: multiple sclerosis (MS), cystic fibrosis (CF), and diabetes mellitus (DM).

**Direct Observation**

A researcher (KMU) provided a brief project overview and obtained verbal assent from staff, providers, and patients (as appropriate) before observation. Initial observation focused on interactions among people, processes, and technology, with the focus narrowing in response to data analysis. The observer remained in an unobtrusive location, watching computer use whenever possible, and recorded detailed field notes to assess the function of technology. Notes included details such as use of EHR functions, comments from providers about the EHR, how different types of information were collected and recorded, and transfer of information among different roles, and descriptions of hand-offs.

As time allowed, the researcher asked open-ended questions to clarify observations, such as about policies, procedures, or other potential influences on workflow. For example, while the researcher was observing a patient-provider interaction, the patient mentioned calling the clinic’s after-hours number for assistance and the on-call provider prescribed a new medication. However, the patient’s regular physician was not aware of the change and the information for the new medication was not in the EHR. After the patient visit was completed, the researcher asked the provider about clinic policies, procedures, and normal routines related to documenting after-hours calls. Other questions related to clinical decision-making processes.

Those observed included clinical receptionists, dietitians, social workers, nurses, nurse practitioners, resident physicians, fellows, and attending physicians. The researcher observed both routine and non-routine situations in clinic work areas, private offices, hallways, and in examination rooms during patient visits. Routine work activities observed included patient check-in, patient intake, patient examination, diagnostic tests, prescribing, patient education, patient check-out, handoffs between providers, and communication processes. Non-routine situations included patient emergencies, such as an extremely high blood glucose level in a patient with DM. The researcher also obtained blank copies of all paper artifacts used during patient care such as laboratory test order forms, provider data recording tools, and patient data forms.

**Analysis of Observation Data**

Data were analyzed inductively, formulating conclusions based on data rather than seeking to confirm a-priori hy-
potheses. Analysis occurred throughout data collection to extract recurrent themes and to guide subsequent data collection. Field notes were transferred to an electronic notebook with functionality to organize and help code data. An open coding approach was followed, including cycles of initial and more focused coding. Initial coding was open-ended, occurred as close as possible to data collection, and involved marking recurring observation events, descriptions, and concepts. Focused coding organized and synthesized the initial coding results.

Both initial and focused coding assisted in focusing subsequent observations by, for example, highlighting areas where additional information was needed. Analysis processes, theme development, and observation refinement were reviewed and discussed extensively by all manuscript authors.

Model Development
Data analysis guided development of models representing workflow and information flow processes and relationships within each clinic. We applied Hierarchical Task Analysis, modified for a broader systems-level focus, to develop workflow models. Analysis of observation data identified the details and sequences of routine care processes in each clinic, responses to non-routine events, and elements of workflow involved in patient care coordination. The details were then arranged sequentially in graphical workflow representations. Preliminary workflow model versions focused on individual roles, such as physician or nurse. With more data, the models expanded to incorporate multiple perspectives on workflow throughout the clinic and relationships among activities.

The information flow models were based on Soft Systems Methodology and focused on the transfer of information between individual actors (e.g., patient or nurse) including information required to perform activities and information generated during activities. The models also depicted both electronic and paper-based repositories of information. During analysis of field notes, we identified actors and roles impacting direct patient care and administrative functions. We identified the information systems used by the actors, the types of information transferred among actors, and information-related processes occurring outside of our data collection frame (i.e., filling a prescription).

Semi-Structured Interviews
We conducted 30–45 minute semi-structured interviews with participants in each clinic to confirm observations and assess the structure of clinic-specific models. Interview participants included three attending physicians, one fellow, two nurse practitioners, a nurse, and two dietitians. The interview sampling frame sought to fully represent the range of users in each clinic, but subject availability and willingness to participate limited selection. Interviews were audiorecorded and later transcribed.

The interviews used an open-ended conversation guided by subject responses, with a common set of questions (see data supplement) providing a high-level structure. After participant assent, the researcher showed the subject their clinic’s workflow and information flow diagrams. After familiarizing the participant with the models, initial questions focused on model sections specific to the subject’s role. The participant was asked how well the model described their actual workflow. The interviewer probed subject responses to clarify difficult to observe workflow details such as decision-making processes and to obtain additional information about EHR use.

Analysis of Interview Data and Revision of Models
The transcribed interview data were transferred to the electronic notebook. Data analysis focused on differences between observed and reported actions, which typically related to elements of decision-making and task order. Both types of models were revised in response to interview data.

Results
We conducted more than 150 hours of direct observation and nine interviews across the three clinics. A researcher (KMU) observed 56 hours of patient care and other activities in the MS clinic, which included observation of 41 patient-provider interactions. Observation was conducted in the CF clinic for 44 hours, during which 48 patient-provider interactions were observed. The researcher spent 52.5 hours in the DM Clinic, including observation of 68 patient-provider interactions. Interview subjects included: one participant from the MS clinic, three participants from the CF Clinic, and five participants from the DM Clinic.

During data analysis, we compared workflow, information flow, and relationship with technology to understand cross-site similarities and differences. We developed models of workflow and information flow and assessed the role of technology as a partner within and across the clinics. Based on common elements and unique attributes of each environment, we also developed a set of ten guidelines for HIT design for chronic disease care (Table 1).

Overview of Clinic Characteristics
The three clinics represented a range of disease characteristics, patient populations, and clinic attributes (summarized in Table 1). Applications should be designed to allow customization for disease-specific needs.

Table 1: Guidelines for HIT Design for Chronic Disease Care

- Applications should be designed to support shared needs and behaviors in chronic disease care.
- Applications should be designed to allow for customization for disease-specific needs.
- Applications should allow customization to support the needs of different types of users.
- New approaches for information input into the EHR should be explored.
- Efficient transfer of data from medical devices into the EHR should be supported.
- Information scanned into the system should be searchable, quickly viewable, and more accessible.
- Alternate methods of displaying the longitudinal data for individual patients should be investigated to determine if they assist in the cognitive processing of electronic data.
- New tools and processes should be as efficient as existing approaches or yield significant benefits to users to promote adoption.
- The reasons behind organizational and personal resistance to technology should be addressed to promote adoption.
in Table 2). Of note, those clinics in the main clinic building were closest to the informatics support center. Clinic providers and staff ranged from EHR “super users” and technology champions to novice users.

Patterns in Workflow and Information Flow

Workflow Models
Each clinic had an overall pattern of work that we summarized graphically in workflow diagrams. The workflow diagrams show sequences and patterns of tasks in the clinics, as well as information modalities (telephone, paper, computer) used in specific work tasks. The full workflow diagrams for all three clinics are available in the data supplement.

Although specific details of workflow differed between clinics, the clinics shared many common workflow elements, as shown in Figure 2. Of note, between appointment contact was a core component of care in each clinic, as were expectations of regularly scheduled return visits. Providers in all three clinics used the EHR, although there was appreciable intra- and interclinic variability in reliance on the system and the timing of the interaction. Providers in the MS clinic frequently relied on paper charts maintained by the clinic. In contrast, the CF and DM clinics did not maintain paper charts. All care was documented in the EHR as either scanned notes or electronically created documentation. All three clinics used the EHR for record review and secure messaging. Two specific portions of the care cycle will be discussed in detail to illustrate the similarities and differences: the hand-off from nurse to provider and the post appointment completion activities.

In all clinic encounters, a hand-off from the nurse to the provider (Figure 3, available as an online data supplement at http://www.jamia.org) occurred as patients transitioned from intake to provider management. During the course of the study, the hand-off processes in all three clinics consisted of nurses gathering various paper forms, placing them in clinic-specific locations, and writing the patient name on a form or Whiteboard. Nurses used paging systems or check marks on a paper schedule to notify providers when patients were ready. The purpose of the hand-off process was to transfer patient information and, regardless of data type, the information transfer process was primarily paper-based.

Three main differences were identified: visit structure, types of information transferred, and allocation of physical space.

Table 2 ● Clinic Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Multiple Sclerosis</th>
<th>Cystic Fibrosis</th>
<th>Diabetes Mellitus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Rehab hospital away from other clinics and support services</td>
<td>Main clinic building</td>
<td>Main clinic building</td>
</tr>
<tr>
<td>Self-described use of HIT*</td>
<td>“Fully electronic”</td>
<td>Enthusiastic HIT proponents</td>
<td>Usage described as variable depending on provider</td>
</tr>
<tr>
<td>Involvement in HIT development</td>
<td>Not involved</td>
<td>Some partnership to customize EHR</td>
<td>Limited partnership to develop disease management tools in EHR</td>
</tr>
<tr>
<td>Computer availability</td>
<td>Each examination room, charting room, provider offices</td>
<td>Each examination room, nurses station, charting room, hallways, provider offices</td>
<td>Each examination room, nurses station, charting room, provider offices</td>
</tr>
<tr>
<td>Computer systems used</td>
<td>Practice management software, EHR</td>
<td>Practice management software, EHR, disease registry software</td>
<td>Practice management software, EHR</td>
</tr>
<tr>
<td>Care locations</td>
<td>Examination rooms, hallways</td>
<td>Examination rooms</td>
<td>Examination rooms, provider offices</td>
</tr>
<tr>
<td>Patients managed by clinic</td>
<td>3000</td>
<td>140</td>
<td>6000</td>
</tr>
<tr>
<td>Attending physicians</td>
<td>2</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Other physicians</td>
<td>Occasionally 1–2 residents or fellows</td>
<td>Typically 2–3 fellows</td>
<td>Occasionally 1–2 residents or fellows</td>
</tr>
<tr>
<td>Nurses</td>
<td>1 full-time nurse, 2 part-time nurses</td>
<td>2 intake nurses, 1 CF nurse-specialist</td>
<td>5 intake nurses, 2 DM nurse educators</td>
</tr>
<tr>
<td>Ancillary providers</td>
<td>None</td>
<td>1 dietitian, 1 social worker</td>
<td>2 dietitians</td>
</tr>
<tr>
<td>Dedicated examination rooms</td>
<td>4</td>
<td>4–5</td>
<td>15</td>
</tr>
<tr>
<td>Recommended minimum visit frequency</td>
<td>Every 6 mo</td>
<td>Every 3 mo</td>
<td>Every 3 mo</td>
</tr>
</tbody>
</table>

Notes: *Initial descriptions of HIT use provided by key informants during preliminary interviews.
The number and type of providers in each clinic directed the structure of patient visits. Patients in the CF and DM clinics had access to ancillary providers such as social workers and dietitians; patients in the MS clinic did not. Variations in hand-off processes related to providers were most pronounced in the DM Clinic, due to the large number and different types of providers. Nurses in the DM clinic described a binder maintained by the charge nurse to track provider preferences regarding patient intake and hand-off processes, such as frequency of point-of-care tests and types of printed documentation. Appointments in the DM clinic had a structured schedule; a patient seeing both a dietitian and a physician on the same day was given a scheduled appointment time for each provider. In contrast, the CF clinic followed a more fluid approach to patient visits with ancillary providers, with one scheduled visit time that covered all care providers. These scheduling differences fundamentally altered workflow patterns between clinics.

The types of data transferred in the hand-off process also varied. The MS clinic primarily used qualitative data such as assessment of gait and patient reports of disease status. The DM clinic relied heavily on quantitative data such as blood glucose and glycosylated hemoglobin values. In the CF Clinic, both types of data were used. Management of space also affected workflow. In the MS and CF Clinics, a patient’s entire appointment (from intake to provider workup and treatment) took place in one examination room. In the DM Clinic, moving the patient from the intake area to either an examination room or a secondary waiting area was part of the hand-off process.

In contrast to the nurse hand-off, the appointment completion activities (Figure 4, available as an online data supplement at http://www.jamia.org) often involved the EHR. Across all clinics and providers, on appointment completion the patient visit was documented in the EHR. Nevertheless, there were multiple differences in workflow related to appointment completion, organized into three groups: the role of paper versus the EHR, disease-specific documentation needs, and variability in EHR usage among clinicians. Providers and staff entered patient visit documentation into the EHR through four different routes: scanned handwritten notes (MS, DM), phone dictation (MS), dictation software (DM), and typed by the provider (CF, DM). Differences in disease-specific documentation needs were typically managed through the development of clinic-specific templates in the EHR. For example, providers in the CF clinic used a common note template designed by one of the clinic providers.

We previously discussed in detail EHR usage variations among providers in the DM clinic. Similar variations existed among providers in all clinics and directly impacted workflow. In addition to variations in documentation modality, we observed a wide-range of EHR usage patterns during patient-provider visits, as shown in Table 3. While some providers started notes in the EHR while with patients, other providers recorded information on paper and entered notes in the EHR during appointment completion, frequently after the patient left.

**Information Flow Models**

We developed graphical models of information flow for each of the three clinics (available in the data supplement), as well as a generalized model of chronic disease care information flow (Figure 5). A common element across all the information flow models was the patient as an information hub. We found that patients provide and receive substantial amounts of information related to their care, but did not interact with the EHR. One provider described the role that patients play in disease management by saying:

> When you have a chronic disease, it’s not something that a doctor does to the patient, it’s something that the doctor and the patient do together.
Providers and staff used HIT applications in the clinics for information access, input, and communication. Information access involved using the EHR to review existing data. Information input involved using the EHR to enter new data or edit existing data. Communication involved using functions of the EHR to communicate with other people or entities (e.g., pharmacies). Different types of users employed subsets of these three main EHR functions (Table 3).

Providers used six types of information to different degrees depending on location: laboratory results, radiology images, other test results, external medical records, internal medical records, and patient-reported status information. We also identified eight different sources of information: EHR, paper records, fax, mail, e-mail, documents brought by patient, patient verbal reports, and device-generated data.

Existing HIT resources supported varying degrees of information presentation and synthesis. All clinics noted challenges using the EHR to integrate information from external providers, most of which was presented as scanned images in the EHR. The scanned information was also not incorporated into summaries of patient data over time.

**Relationship between Workflow and Information Flow**

Workflow and information flow were interconnected, and were even more significant in integrated practice environments like the CF and DM Clinic, where patients interacted with multiple providers during a single visit. For example, provider differences in choice of input modality for patient

### Table 3 - Variations in HIT use Among Provider Types

<table>
<thead>
<tr>
<th>Use of HIT for:</th>
<th>Multiple Sclerosis Clinic</th>
<th>Cystic Fibrosis Clinic</th>
<th>Diabetes Mellitus Clinic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Information Access</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review new and previous test results</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Review diagnostic images</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Review previous notes</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Review notes from other providers</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Review medications</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td><strong>Information Input</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Document patient vitals and disease specific variables</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Update problem and medication lists</td>
<td>RN</td>
<td>RN</td>
<td>RN</td>
</tr>
<tr>
<td>Download glucose meters</td>
<td>RN</td>
<td>RN</td>
<td>RN</td>
</tr>
<tr>
<td>Write notes</td>
<td>MD AP</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Write electronic prescriptions</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Send and receive electronic messages to other staff members</td>
<td>MD RN</td>
<td>MD RN</td>
<td>MD RN</td>
</tr>
<tr>
<td>Check schedule to see if patients have arrived</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Review notes from other providers</td>
<td>MD</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Write patient letters</td>
<td>MD AP</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>Communicate with patients</td>
<td>RN</td>
<td>RN</td>
<td>RN</td>
</tr>
</tbody>
</table>

**Legend:**
- MD: Medical Doctor
- RN: Registered Nurse
- AP: Nurse Practitioner
- NP: Ancillary Provider

Physicians and Nurses were present in all three clinics. Ancillary Providers were only present in the CF and DM clinics. Nurse Practitioners were only present in the DM clinic.
visit notes and the timing of entering these notes into the EHR were often explained as being related to efficient workflow. Provider choices also impacted information flow and the workflow of others. Handwritten documentation required other staff members to scan the documents and, in the case of the MS clinic, to maintain paper charts. Moreover, paper documentation created a time lag before the information was available to others. Phone dictation required the provider to review the dictated document after transcription, again causing a time delay between the visit and information availability. Dictation software and notes typed by the provider resulted in immediate availability of information and did not involve other staff.

**Technology as a Partner**

**The Role of the Electronic Health Record**

Providers and staff throughout the three clinics expressed satisfaction with many of the EHR features, concurring with findings of survey-based studies of previous users of the same EHR system. As noted by one provider:

> I love the computer. I think it's fantastic. I love StarPanel. I love the electronic medical record. I love having access, point-and-click access, to the problem list, the medication list, all the labs, all the previous entries from other clinicians, appointments, oh, I just couldn't live without it now. I mean, I'm totally dependent on it.

However, providers had not fully adopted the EHR system throughout these clinics. While some functions of the EHR had become team players in providing care, other functions were perceived as barriers to efficient care delivery. One provider explained his relationship with the EHR by saying:

> The computer is useful, but again, you know, there are layers you go through the computer so you can't access that information, you can't—it's not like flipping through a chart. It's like looking at a book versus looking at something on a screen.

Subjects commented that they were unaware of or unfamiliar with many of the EHR features. For example, the provider who earlier described being totally dependent on the EHR also said:

> And I know that I underutilize it [the EHR]. I know that there are probably a lot of things that I could use it for and I don't even know what I don't know.

Many providers lacked time to learn about additional EHR features. This was complicated by limited documentation for end users and multiple feature access options. Many providers expressed concerns about the amount of time required to become proficient in EHR use.

Providers found both existing and new functions challenging to learn. Providers in the CF and DM clinics described a steep learning curve and difficulty becoming efficient in use of electronic prescribing functionality implemented during the course of the study. One provider discussed patients becoming restless while she was trying to learn how to use the functionality and switching back to handwritten prescriptions as a result. As one provider lamented:
I just spend more and more time here. Every time they roll out something wonderful, it just takes more of my time.

Another provider, who had decided not to use the prescription-writing feature, discussed the balance between the value of new technologies and the time required for use:

I’d be interested in anything that improves patients’ safety. At the same time, I’m just very cognizant of anything that would involve new responsibilities by the physician … if you can show that it saves time, then I think it’s a different issue.

These examples echo comments heard repeatedly across all three clinics regarding time, effort, and benefits of EHR use. Despite widespread deployment of computers in all three clinics, both the location and the number of computers constrained EHR use. Multiple computers were located outside of examination rooms in each clinic, but heavy demand created access problems in some areas. While computers were available in every exam room in all three clinics, one provider described her hesitation in using the computer in the exam room by saying:

It feels very awkward to me to sit there and type while they are looking over my shoulder and I can’t look at them. I mean, I just think it impacts the relationship building to do that.

This concern about the impact of EHR use on the patient-provider relationship concurs with previous research showing changes in communication and cognition resulting from EHR use, although other studies have shown EHR use may have a positive impact on patient perceptions of patient-provider interactions. Providers not proficient in typing had difficulty using the EHR, particularly in the examination room. These providers typically recorded information on paper and dictated their notes later, adding to the amount of time required for documentation work. Providers who entered notes into the EHR while with patients described a minimal amount of time required after appointments to complete clinical documentation. In contrast, providers who did not document in the EHR while with patients complained about excessive documentation burdens:

I just don’t do that [enter information while with patients]. I have to do it between patients. That’s what I do during my lunch breaks, it’s what I do at the end of the day, it’s why I’m here until 6:30 or 7:00 at night.

The user interface design constrained data entry in some cases. For example, the EHR did not support a homunculus, a graphical representation of the human body, used to document neurological status in the MS clinic. The providers documented this information on a customized paper form that was later scanned into the EHR.

Overall, several EHR features were viewed with ambivalence by users. An example of this is the Message Basket, an EHR feature that enables staff and providers to send and receive messages about patient care. While providers appreciated the value this feature, they also found it time-consuming to learn and use. One provider described the Message Basket feature as useful but also a “time-sucking pit”.

### Communication

We observed the use of multiple communication modalities, both synchronous and asynchronous, within the clinics

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Communication Modalities Used in All Three Clinics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong> Synchronous</td>
<td><strong>Used By</strong></td>
</tr>
<tr>
<td>Face-to-face conversation</td>
<td>All subjects</td>
</tr>
<tr>
<td>Telephone</td>
<td>Admin ↔ Provider*</td>
</tr>
<tr>
<td>Fax</td>
<td>External provider ↔ Provider</td>
</tr>
<tr>
<td>Email</td>
<td>Admin ↔ Provider</td>
</tr>
<tr>
<td>Paper forms</td>
<td>Admin ↔ Provider</td>
</tr>
<tr>
<td>Voicemail</td>
<td>Admin ↔ Provider</td>
</tr>
<tr>
<td><strong>Type:</strong> Asynchronous with notification of receipt</td>
<td><strong>Used By</strong></td>
</tr>
<tr>
<td>Patient portal messages</td>
<td>Admin ↔ Provider</td>
</tr>
<tr>
<td>StarPanel Message Basket</td>
<td>Provider ↔ Provider</td>
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<tr>
<td>Email</td>
<td>Provider ↔ Provider</td>
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<tr>
<td>Fax</td>
<td>Provider ↔ Provider</td>
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<tr>
<td><strong>Type:</strong> Asynchronous without notification of receipt</td>
<td><strong>Used By</strong></td>
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<tr>
<td>Email</td>
<td>Admin ↔ Provider</td>
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<tr>
<td>Fax</td>
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<td>Paper forms</td>
<td>Admin ↔ Provider</td>
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<td>Voicemail</td>
<td>Admin ↔ Provider</td>
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</table>

*Provider: Physician or Nurse Practitioner.

(Table 4) to support communication among physicians, nurses, ancillary providers, administrative staff, and patients. Several previous studies demonstrated the complex, interruption-oriented communication patterns in hospital settings and we observed similar complexity and interruptions in the ambulatory setting. Synchronous modalities, such as face-to-face conversation, were commonly used to direct workflow and resolve issues. Synchronous communication often provided fast answers but also interrupted others’ work, as discussed in previous studies. Asynchronous communication modes also caused interruptions. In the DM Clinic, intake nurses normally paged providers to notify them when intake was completed. DM providers noted that these pages prompted them to wrap up their current patient visit. Although the page required no direct action, it interrupted workflow and modified provider behavior.

Paper artifacts played an integral role in communication in all three clinics. The clinics used a paper process for ordering laboratory tests with multiple clinic-specific forms. In the DM clinic alone, three distinct forms were used depending on test type. Participants commented that the ordering process was time-consuming and they would prefer an electronic order-entry system. Paper artifacts were also used for quality improvement. For example, the CF clinic used a checklist to encourage compliance with recommended treatment guidelines. On the day before each patient’s visit, a technician manually prepared the checklist by compiling the patient’s test results and treatment recommendations. Nurses combined this checklist with other paperwork during the patient intake process, providers used and updated the form during the patient visit, and a technician manually entered the resulting data into a national disease registry.
after the visit. The checklist served both as a prompt for evidence-based treatment as well as a tool to coordinate patient care activities among different types of providers (e.g., physician, dietitian, social worker). Our results concur with previous research discussing the importance of paper artifacts, such as sign out sheets used during inpatient rounds, play in healthcare communication.

Discussion and Recommendations

Our results demonstrated the strengths and the weaknesses of an existing HIT infrastructure. Although the EHR used in the study clinics is a locally developed system, the observed positive and negative attributes of the HIT systems and the implementation process are not unique to this environment. Clinic staff and providers documented and tracked patient status over time. Many providers integrated the EHR into their routine workflow. However, the primary care orientation of the EHR design did not fully support the needs of chronic disease care providers. Based on our results in three diverse ambulatory clinics, we developed a framework of ten guidelines for the design and implementation of HIT solutions for chronic disease care (Table 1). The key commonalities and significant differences among the clinics support a modular approach to HIT design for chronic disease care. Core functionality could support common needs across clinic environments including: tracking patient disease status over time, displaying previous treatments and responses to previous treatments, analyzing trends, assisting with patient education materials, and facilitating communication with patients and throughout each clinic. The core HIT functionality could be supplemented with disease-specific modules. For example, the types of information recorded in notes varied between clinics as a function of disease-related information requirements. Specialized templates may be necessary to meet unique information needs. However, many components of disease-specific HIT modules could be repurposed for multiple clinics. For example, a generic nutrition module could be designed to support the needs of diverse specialty clinics (e.g., CF, DM, obstetrics, gastroenterology) where tracking dietary information is an important component of care. Additional specialized modules should include qualitative data tracking, tailored order entry and prescription writing, disease-specific self-management support, and graphical input elements (e.g., the homunculus would also be useful in neurology, orthopedics, and physical therapy). In addition to customizing technology to meet disease-specific needs, HIT design should support different users’ needs. Clinic personnel collect and enter different types of data and have different information needs depending on their role and responsibilities within the clinic. Interfaces that could be customized to support individual workflow needs and preferences could improve efficiency, user satisfaction, and data quality.

As with any “engineering” process, it is vital to have proper design strategy. Developers and implementers did not have comprehensive requirements for each chronic disease clinic during initial EHR implementation; later phases of implementation did not include time to gather and incorporate this information into design. Although some modules to assist with chronic disease care had been developed, the three clinics did not have access to these modules during the study period. Addressing new requirements as they arise in implementation is a necessity in user-responsive modular HIT development.

Entering information into existing HIT, especially during interaction with patients, was difficult for many providers. Barriers included lack of typing proficiency, data collection form design, and hardware placement. New input modalities, such as tablet computers and software-based solutions like graphical forms, should be developed and evaluated. Advanced speech recognition software could also facilitate data entry.

Data are entered into the EHR from multiple sources and in multiple formats including medical device downloads, scanned paper forms and handwritten notes, and information recorded electronically. As time passes, the volume of information in the EHR increases tremendously. Chronic disease care providers are routinely required to search and filter through this disparate collection of information in an attempt to find the data they need at a particular time; the EHR must facilitate this process. Providers also need to rapidly and accurately synthesize information to formulate a coherent picture of patient status over time and then to inform treatment decisions. Providing longitudinal views of patient disease history is a requirement of HIT for chronic disease care.

The study also highlighted the challenges of HIT adoption in chronic disease care. Our results demonstrated that end users will create inefficient, but policy-compliant, workarounds to accomplish tasks when the HIT does not meet their needs. Perception of system impact on time and workflow can be as important as the actual impact itself. Barriers to adoption must be investigated and addressed to bridge implementation chasms. The inadequate transfer of knowledge among HIT designers, implementation teams, and end users can inadvertently create barriers to adoption. Multiple providers stated that they were aware of or proficient in using only a small fraction of the EHR’s functionality. Finding better ways to help end users become proficient with the EHR features they need, including addressing user interface design challenges, would enhance technology adoption.

Study Limitations

This study provides a picture of workflow, information flow, and computer use in three chronic disease clinics at one Academic Medical Center. We selected qualitative methods based on the research questions. Quantitative methods such as time-motion studies could supplement the understanding of aspects of workflow in ambulatory chronic disease care. A single researcher (KMU) collected the data, introducing the potential for observer bias. To address this potential limitation, study procedures and data were extensively reviewed and refined by the entire research team. In addition, interviews were conducted with clinic personnel to obtain feedback on the validity of observations and conclusions as a form of member-checking. The three clinics all used the same EHR system. Researchers previously documented high levels of satisfaction among primary care providers using this same EHR, but before this study little was known about usage patterns and satisfaction among specialty care providers. A different EHR system would likely impact
workflow in different ways, underscoring the need for additional qualitative research to triangulate the needs of specialty care providers. Chronic disease care was only studied in disease-specific clinics, yet primary care physicians also provide chronic disease care. Changes to policies, procedures, staff, and informatics tools were implemented during the course of the study. While the dynamic nature of the work environment presented challenges, we collected data on these changes as part of the study and incorporated this information into our analysis.

**Conclusions**

This study examined similarities in workflow and information flow between three ambulatory chronic disease clinics. Differences between the clinics and within each clinic were also identified.

The results showed that existing technology did not fully support users’ workflow or information needs. Many users had difficulty with the available methods for data input. We identified the challenge of using a relatively flat EHR structure to provide longitudinal care as a significant barrier to full adoption of informatics in this environment. Gaps between how informatics tools are actually used and institutional expectations of use were identified, as were workarounds developed by end-users to bridge gaps between available functionality and their real-world needs. These methods may be useful in future work examining process improvement, informatics tool adoption, and design of HIT applications.

Health Information Technology has the clear potential to support improved healthcare delivery and better patient outcomes. The need for effective HIT solutions is especially pronounced in chronic disease care, due to expanding patient populations and disease-related complexities. Understanding workflow, information flow, and provider needs in chronic disease care environments can contribute in developing strategies to maximize HIT use, to enable providers to take full advantage of the capabilities of HIT systems, and to support patients in managing chronic diseases.

**References**