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Executive Summary

Adoption of Electronic Health Record (EHR) systems in hospitals and outpatient clinics is accelerating. EHRs can support and revolutionize the way information is used to provide high-quality and safe patient care. At the same time, however, issues with workflow integration have contributed to slow rates of EHR adoption in some settings, including ambulatory outpatient care. Workflow is a set of tasks, grouped chronologically into processes, and the set of people or resources needed for those tasks that are necessary to accomplish a given goal. Workflow analysis is an integral part of the early stages of the User-Centered Design (UCD) process. UCD is an approach to designing systems and employs both formative and summative methods in order to achieve systematic discovery of useful functions grounded in an understanding of the work domain.

In response to workflow integration challenges with EHRs, clinicians often develop workarounds to complete clinical tasks in ways other than were intended by system designers. A frequent workaround, for example, is copying and pasting text from a previous progress note for a patient to serve as a draft for the current progress note. In this report, two human factors workflow modeling tools, process mapping and goal-means decomposition, were used to collect, visualize, and document insights and the end-user needs to improve EHR workflow for clinicians in outpatient care settings. The findings identified clinical activities that require more relevant and flexible workflows in EHR designs to support end users' needs. Based on the insights generated during collegial discussions with physician Subject Matter Experts (SMEs) and three interdisciplinary team meetings with clinical and human factors experts, we created process map visualizations and a goal-means decomposition diagram.

The insights identified a wide range of opportunities to improve workflow through enhanced functionality with the EHR. Some of the opportunities included:

- At-a-glance overview displays to enable physicians to adapt patient schedules to smooth out predicted workload and better meet work-life balance objectives
- Support for remembering tasks to accomplish during a subsequent patient visit
- Redacting and summarizing laboratory results
- Drafting predicted orders a day before a patient visit to reduce the time to complete the orders during the visit
- Supporting moving from initial working diagnoses to formal diagnoses
- Supporting dropping or delaying tasks under high workload conditions
- Supporting different views of a progress note based upon role
- Distinguishing new documentation in a progress note from copied information from a different progress note
- Supporting communication with specialist physicians about referrals and consultations
- Tracking scheduled consults and review of laboratory results

Targeted recommendations for EHR developers and ambulatory (outpatient) care centers to improve workflow integration with EHRs are proposed to increase efficiency, allow for better eye contact between the physician and patient, improve physician's information workflow, and reduce alert fatigue. These recommendations cover scenarios such as supporting tasks accomplished over multiple interactions with an EHR by multiple users, for example, a nurse practitioner drafting medication orders that are verified and completed by a physician.

These recommendations provide a first step in moving from a billing-centered perspective (i.e., focusing on ensuring maximum and timely reimbursement) to a clinician-centered perspective where the EHR design supports clinical cognitive work, such as moving from an initial working diagnosis to a formal diagnosis for a complex patient. These recommendations point the way towards a "patient visit management system," which incorporates broader notions of supporting workload management, and supporting the flexible flow of patients and tasks.

1 Introduction: Clinical Workflow Challenges with EHRs

Adoption of Electronic Health Record (EHR) systems in hospitals and outpatient clinics is accelerating.[1] EHRs can support and revolutionize the way information is stored, accessed, shared, and analyzed for patients, patient cohorts, and organizations, creating a foundation for potentially dramatic improvements in quality of care, patient safety, public health monitoring, and research.[2,3,4,5,6,7,8,9,10,11,12] At the same time, however, use errors from design flaws and poor usability with EHRs can negatively affect patient safety.[13] Further, issues with workflow associated with EHR implementation, including inefficient clinical documentation, have contributed to slow rates of EHR adoption in some areas, such as ambulatory care settings[14] and pediatric care[15] and shown increased documentation time with major changes to the nature of documentation in ophthalmic care.[16] Also, a recent survey study indicates that nearly 60% of ambulatory care providers report being dissatisfied with their EHR due to usability and workflow concerns.[17]

The purpose of this report is to demonstrate how applying human factors modeling methods can improve EHR workflow integration into the clinical workflow. Although there are multiple users for electronic health records, for the purposes of this project, the scope was primarily limited to physicians in an ambulatory (outpatient) care setting.

In healthcare settings implementing EHRs, an emerging consensus is that many of the critical risks for the care of patients associated with the use of the EHR are related not just to the system's user interfaces, but also to the usefulness of the system's functionality and workflow.[18] Therefore, for the purposes of this document, we use a unified framework for defining EHR usability: "how useful, usable, and satisfying a system is for the intended users to accomplish goals in the work domain by performing certain sequences of tasks."[19]

For systems used in high-risk environments, where mistakes can result in fatalities, ensuring system usability is a particularly important objective. Usability has traditionally been defined as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."[20] In order to achieve usability in such systems, it is critical to design for usability using best practices from User-Centered Design (UCD). UCD is an approach to designing systems; the approach is informed by scientific knowledge of how people think, act, and coordinate to accomplish their goals.[21] UCD practices employ both formative (for informal suggestions) and summative (for formal validation) practices in order to achieve systematic discovery of useful functions grounded in an understanding of the work domain.

National guidelines have been released to improve usability and patient safety by conducting summative usability tests of EHR software as a part of implementation.[22] An acknowledged limitation of this approach is that it is difficult to identify workflow challenges arising from local implementation decisions and from the variation in the distribution of work across types of users. The Agency for Healthcare Research and Quality (AHRQ) report titled "Incorporating Health Information Technology into Workflow Redesign"[23] concluded that workflow analysis was needed in order to ensure successful health IT implementation. Additionally, in some cases, components that are created to meet the needs of particular types of users (such as physician order entry, nursing and pharmacy order processing, and nursing medication administration documentation) may not interact well with each other.[24]

Workflow has emerged as an issue for EHR adoption, productivity,[25] and professional satisfaction for physicians.[26] Issues with non-optimized workflow include making patient care more fragmented, introducing new risks to patient safety, and requiring more effort in coordination of care.[22,23] For organizations that are interested in increasing the patient's role in shared decision making and tailoring

care to patient characteristics based upon recent evidence, EHRs provide little support and make it difficult for the team members other than physicians to support performing relevant tasks such as entering data from interviewing a patient into a draft of a progress note.[27] Designing for healthcare is confronted by high variability and nonlinear nature of work.[24,25] For example, workflow challenges that have been identified in the literature review include:

- having to log in to multiple systems separately,[26]
- extensive manipulation of keyboards to enter information,[27]
- the number of clicks involved in medication ordering processes,[28-30]
- difficulty in processing orders that are not standard,[30,31]
- difficulties in switching between different paths and screens to enter and retrieve information,[29]
- problematic data presentations such as patient medication profile design,[31]
- clutter of order and note screens,[26]
- difficulty seeing patient names on the screen,[32] and
- missing free text entry and other word processing functionalities.[29,30]

In response to workflow integration challenges with EHRs, clinicians often develop workarounds to complete clinical tasks in ways other than were intended by EHR system designers.[34,35] Workarounds are defined as actions that do not follow explicit rules, assumptions, workflow regulations, or intentions of system designers.[36] The primary reasons for workarounds are improving efficiency, triggering memory, and increasing situational awareness, while additional reasons include knowledge/skill/ease of use, task complexity, and trust issues.[34] Workarounds can be positive improvements or can be suboptimal. A frequent workaround, for example, is copying and pasting text from a previous progress note for a patient to serve as a draft for the current progress note. In one study, 25% of patient charts had text copied from prior clinical examinations, which can lead to confusion, medical error, and medico-legal harm.[28]

It is important to understand the potential impact of workarounds on patient safety. Designing systems that are poorly integrated into workflow may promote workarounds that bypass safety features. For example, poor coordination between bar coding and the medication administration record has been shown to prompt nurses to work around the documentation of medication administration.[29] In addition, EHR documentation may not allow for the variaty of patient care that is routine in healthcare – making the EHR a barrier to capturing important clinical documentation. While the challenge of meeting workflow expectations is considerable, the implications for patient safety are becoming more apparent in the literature.[30] Modeling methods are needed to allow EHR software to accommodate the complexity of clinical environment workflows. Applying these methods will avoid contributing to patient safety issues[31] directly through design flaws as well as indirectly through unsafe workarounds. In addition, there will be more opportunity to provide high-quality care when inefficiencies in documentation and other tasks not directly related to real-time care are reduced.

From a human factors perspective, the unit of analysis for a workflow applies to the entire work system. The work system is composed of the five main elements from the Systems Engineering Initiative for Patient Safety (SEIPS)[40] framework (Figure 1): 1) people (individuals and teams), 2) physical environment, 3) tools and technologies, 4) tasks, and 5) organizational characteristics. The SEIPS framework combines three important aspects for modeling and improving workflow of an EHR: a systems approach, human factors engineering, and safety engineering. The framework indicates that changes made in the work system can have direct and indirect impacts on workflow and corresponding outcomes.

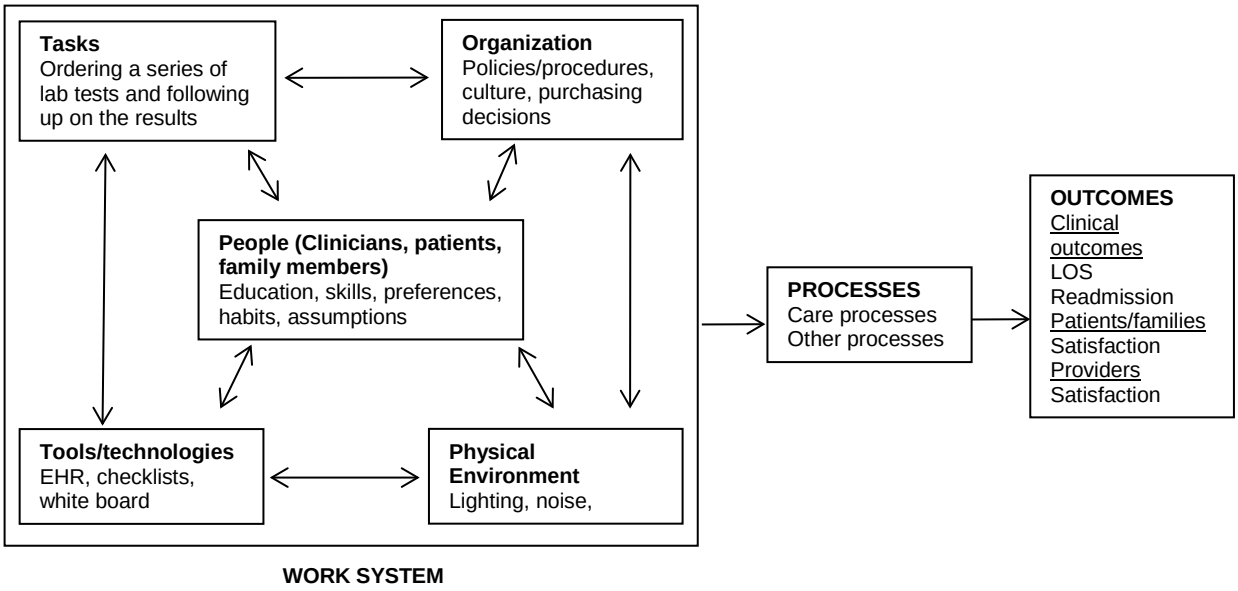

Figure 1. The SEIPS framework for work system elements

From our literature review, workflow, workaround, and work system are defined as follows:
Workflow: A set of tasks, grouped chronologically into processes, and the set of people or resources needed for those tasks that are necessary to accomplish a given goal.[32]

Workaround: Actions that do not follow explicit rules, assumptions, workflow regulations, or intentions of system designers.[35,36]

Work system: The five main elements from the Systems Engineering Initiative for Patient Safety (SEIPS)[40] model are used to define the work system (Figure 1): 1) people (individuals and teams), 2) physical environment, 3) tools and technologies, 4) tasks, and 5) organizational characteristics.

This report focuses on ambulatory (outpatient) care settings. A staffing arrangement in ambulatory care can range from one doctor and a medical / front desk assistant to multiple staff members that may include intake registered nurse (s) and physician (s), who in some cases are supported by a nurse practitioner or physician assistant to provide care and a medical assistant to help with office tasks and paperwork. Most EHRs are designed and used in both ambulatory care and hospital settings, where there are significant variations in staffing and workflow. Workflows that are well documented in one area of care are not necessarily relevant to other areas. For example, a blood pressure reading and documentation for a simple consultation in a clinic and the associated workflow is very different from the continuous monitoring and documentation in a clinic when chemotherapy is being administered.

2 Background of Workflow Modeling for EHRs

There is immense literature on workflow modeling in general, including agent-based modeling and other "humans-not-in-the-loop" modeling. In our review, we focused on approaches to analyzing and depicting workflow from a human factors perspective. Human factors is defined as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance."[33] Human factors modeling methods are based primarily upon extraction of process flow and insights about challenges and variation from Subject Matter Experts (SMEs) during collegial discussions. Our review is not intended to be comprehensive, but does highlight the range of types of workflow models available for use. The application of the human factors workflow modeling tools in Table 1 may vary based on the context in scope (individual clinician, team, and patient-centered), unit of analysis (support for deviations in temporal ordering, level of incorporation of variability, complexity), and feasibility (time, effort).

Decisions on selecting the optimal human factors workflow modeling tool should be informed by multiple factors. Such factors include, but are not limited to, the type of environment where a system will be used; resources that are available for development, testing, and maintenance; and expertise required to properly apply the selected workflow modeling tool. Most importantly, the purpose of the system should determine how it should be modeled. More safety-critical systems require higher-fidelity modeling and a greater level of subsequent validation/evaluation/testing. Tool selection should maximize benefits, tangible and intangible, for the system and its users.

In the examples provided in this document, we show how the methods process mapping and goal-means decomposition can be applied for identifying the EHR workflow integration into the clinical workflow which can inform better design.

Table 1. Human Factors Workflow Modeling Tools for EHRs

Tool	Description
Artifact review[34]	Examination of cognitive artifacts used by users in order to identify tasks, strategies, and information and coordination needs.
Cognitive walkthrough[35]	A step-by-step process of having the user or team of users talk about their thinking and action-taking process while performing specific predefined tasks. It can be done while the user is performing or after they completed performing the task. A think-aloud protocol is often employed, where the user talks about their thinking process while they perform the tasks.
Contextual inquiry and observation[36]	Unobtrusive observation of users performing relevant tasks supported by information technology in their natural working environments. This method is typically used early in the design process of EHR components and conceptualizing possible workflows.
Decision ladder[37]	Analysis of work tasks to determine cognitive strategies and processes used in a complex work domain. Insights represented as decision ladder representations with cognitive states (ovals) and cognitive processes (arrows). Shortcuts employed by domain experts to increase efficiency of decision making are annotated on the representation.
Design audits[38,39]	A design audit determines if a product's user interface adheres or departs from established design practices and standards. Typically a report is produced which lists human factors deficiencies and recommended solutions in order of priority.
Envisioned world technique[40]	Representatives from user groups do table-top or higher-fidelity simulations of how common and challenging tasks would be conducted in the context of using a technology in an envisioned scenario which has not yet been experienced.
Expert reviews/design critiques[41]	Evaluation of the system by experts with knowledge of human factors, usability heuristics, and common workflow challenges in order to ascertain design strengths and weaknesses as well as to recommend improvement opportunities. A structured walkthrough of typical tasks emphasizing the consistency of task flow across tasks and screens can be especially beneficial for identifying workflow issues due to multiple and complex processes.
Goal-directed task analysis[42]	Identification of situation awareness requirements to complete a task from multiple methods, including structured interviews, observations of operators performing their tasks, or analysis of documentation on users' tasks.
Goal-means decomposition[43]	Means (how) for achieving (goals) are displayed visually in a concept map, which are derived from functional analysis.
Hierarchical task analysis[44]	A structured description of tasks that provides an understanding of the tasks users need to perform to achieve certain goals by interacting with software. Tasks are broken down into multiple levels of subtasks.
Participatory design[45]	Involves making the primary and secondary users of the workflow active participants in the design, conception, and evaluation of the workflow and its components.
Process mapping[46]	Flowchart typical process flows with a sequence of process steps and frequently occurring branches as yes/no decision boxes.
Simulated environments[47]	Actual use settings or simulated environments with carefully designed scenarios can be observed to identify workflow issues with representatives from multiple user groups.
Stakeholder identification[48]	Identify and characterize objectives and tasks and their relationship to software requirements for effective workflow support.
Cognitive task/work analysis[49,50]	Identify tasks performed by primary and secondary users. Analyze which tasks are challenging, including due to goal conflicts, coordination across roles, and heavy reliance upon overloaded cognitive resources (memory, attention).
Workload assessment[51]	Focusing on determining user workload for different tasks in the workflow, with the ultimate goal of reducing workload (physical and mental) without compromising the work quality.

3 Application of Human Factors Workflow Modeling Tools

Process mapping and goal-means decomposition were selected to demonstrate that the application of human factors workflow modeling tools can improve EHR workflow integration into the clinical workflow. Based on the insights generated during collegial discussions with physicians, Subject Matter Experts (SMEs), and three interdisciplinary team meetings with clinical and human factors experts, we created process map visualizations and a goal-means decomposition diagram.

This approach was purposefully selected in order to illustrate human factors approaches to identify issues and opportunities with workflow that could potentially be addressed by EHR developers independent of implementation decisions at the local level, or by ambulatory care clinics independent of the particular EHR which is implemented.

In order to apply and exemplify these techniques, the human factors experts held the discussions with several physicians with experience in ambulatory care settings. The SMEs were presented with a description of the topics for discussion; the description explained that the purpose of the discussion was to utilize their subject matter expertise in order to better understand the workflow for a typical return patient grouped by the periods "before the visit," "during the visit," and "after the visit."

SMEs then discussed with interactive guidance from the investigator, a verbal walkthrough of a typical return visit and were asked to reflect upon and highlight challenging areas with the workflow that related to interactions with their EHR.

These physician SMEs had experience with different EHRs, represented different areas of specialty and primary care, and had a diverse perspective on the ideal level of integration of EHRs into routine and exceptional workflows. They included both males and females and an age range from approximately 30 years to 50 years old. A series of three focused interdisciplinary team meetings were held with human factors, informatics, and physician experts to generate the workflow models and accompanying insights for improving workflow. Notes during the discussions were taken by the human factors experts, and were shared within 24 hours following the discussion with the SMEs who had the opportunity to correct and augment the clinical information. Minor corrections were provided following two of the discussions, such as correcting the spelling of the blood condition eosinophilia (originally typed in the notes as eocenophillia). The notes across the discussions were compiled around related events or topics. Emerging insights were discussed among the authors of this report during scheduled meetings and as email discussions. Insights were supported, confirmed, and in some cases reframed by published studies in the literature and by related public posts to establish converging evidence.

The process model and goal-means decomposition were iteratively generated and revised over a series of meetings. The representations were constructed with a commercial flowchart program. All of the SMEs were provided the opportunity to review and make corrections to the final draft of the document. The draft included all of the workflow diagrams constructed from their input and the interdisciplinary team meetings, which represents a high-level depiction of the primary steps in the actual workflow using an EHR for an uncomplicated return patient. Four of the most important steps from the perspective of a physician provider are depicted in additional detail: ordering labs, ordering images, ordering medications, and ordering consults.

Figure 2 is a generalized portrayal of workflow, and thus may vary when customized for different work settings. Choices about what staff perform what roles will modify workflow, and individual clinician preferences will influence what steps are performed in what order and by what personnel, thus the step

sequence and order may vary. Even for a particular clinic at an ambulatory care center, it is anticipated that workflow will vary based on whether the physician is ahead of or behind schedule. Nevertheless, a process map is a useful representation in that it identifies prerequisites for certain steps, distinguishes steps which are required for regulatory/certification purposes from other activities, and identifies the primary typical bottleneck, which is the "during the visit" portion of the process map. Workflow variations which reduce bottlenecks are anticipated to speed EHR adoption and increase efficiency of use, and thus improve efficiency, usability, and safety due to reductions of unsafe workarounds and opportunity costs from less time for patient care provision during the visit.

Steps in the workflow are visualized as an overview at a high level of detail in Figure 2 for EHR interactions related to a patient visit with a physician as primary care provider for an established patient who is returning for a routine visit. These steps are grouped by the following "buckets":

1. Before the patient visit (approximately 1 to 3 days ahead)
2. During the patient visit
3. Physician encounter
4. Discharge
5. Documentation

Next, we have grouped insights from our discussions with SMEs into the five categories. We have chosen to represent the insights in the words of the SMEs to the extent possible, and the focus is on a physician interacting with an EHR without support by a physician extender or case manager related to a patient visit. We have annotated where particular steps are required for compliance purposes (for the Meaningful Use (MU) requirements, for Medicare billing, for accreditation by The Joint Commission).
For example, "verify medications and allergies" is a required step where most EHRs require physicians to click "verify" after viewing a medication list and an allergy list. SMEs viewed this as a required activity that is done without much thought (just to navigate to another screen/task). On the other hand, physicians need to verify thoroughly that medications which they order, particularly if dosages are changing or they are high-risk, have correct dosages. This step will generally occur before explaining to the patient what they need to do. This process (i.e., "verify") could be better supported with the EHR, particularly if the information is provided at the appropriate time in the workflow and does not require actions to document that the activity occurred. In other cases, the intent of the requisite compliance steps is accomplished best according to the SMEs at different times or by different users to support clinical workflow without interruptions.

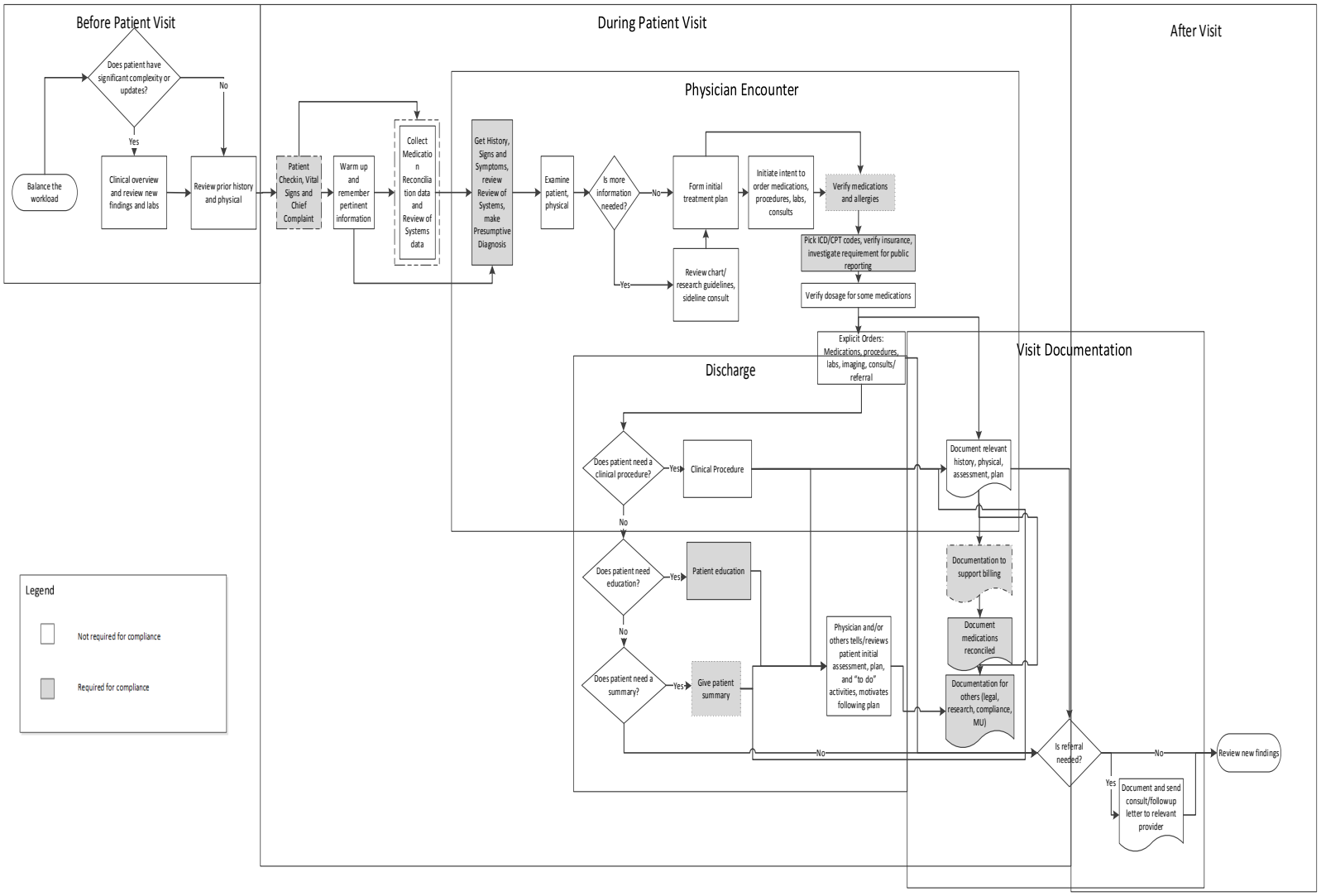

Figure 2. Overview process map for EHR use related to returning patient visit in ambulatory care

A. Before the patient visit

In Figure 3, there is an example of the process steps related to activities occurring with the EHR before the visit. These are:

- Balance workload,
- Clinical overview and review new findings and labs, and
- Review prior history and physical.

There was high variability in whether and how physicians used information from the EHR in order to schedule patients in a way that would allow adequate time for challenging or new patients, meet quality of work-life needs (i.e., not have one or two isolated visits scheduled during a single day), or coordinate with other physicians in their practice (i.e., help out a colleague by adding a patient). All the SMEs emphasized that only about 10% to 25% percent of the patients required extensive review of historical information, reviewing new findings and laboratories prior to the in-person visit with the patient, or searching for guidance about a treatment plan in the scientific literature. Several of the SMEs reviewed the prior history and physical exam findings for every patient, either the night before, the morning before, immediately prior to seeing the patients, or at the beginning of the in-person interaction with the patient.

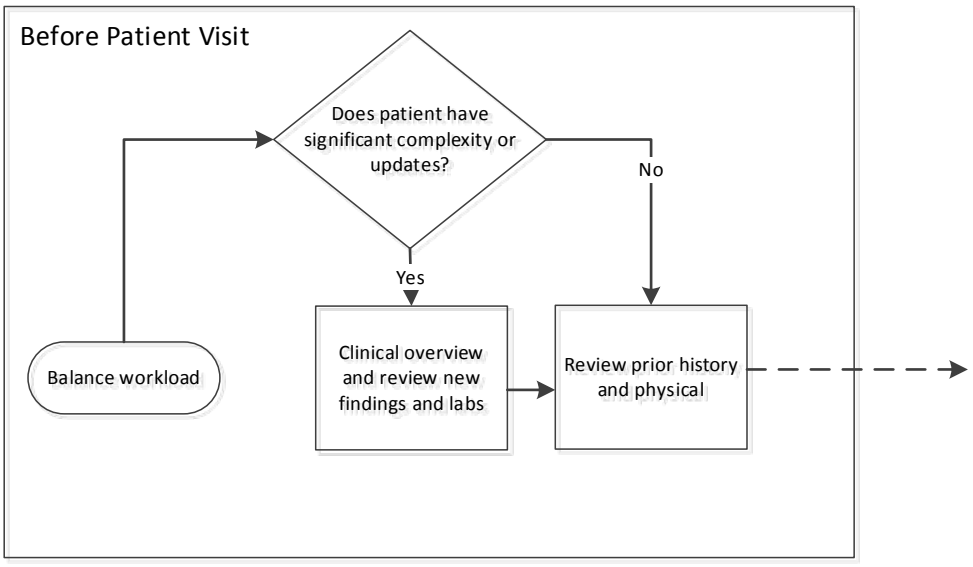

Figure 3. Process map for activities conducted before a returning patient visit with the EHR

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Opportunities for providing support via the EHR for cognitively challenging tasks suggested by the SMEs are:

3.A.1 Scheduling support with at-a-glance overviews of patients for the day: Up to several days prior to the visit, having the ability to get a "gist" of the overall workload for a day can be supported by knowing "at a glance" by viewing an overview of scheduled patients whether patients are routine as compared to new or particularly challenging patients (e.g., complex medical case, noncompliant patient). Of course, this kind of a display would depend upon accurate characterization of the patients when the information is entered. One SME described that looking at the size of a paper chart was a cue to how complex or challenging the patient was,

which is not typically displayed at the top-level view in EHRs with document icons which do not vary based upon length, and that looking at the last note, hospital admission notes, and operation notes prior to seeing the patient was easily accomplished in this situation by opening and flipping through a paper chart. The timeliness of patient care can be improved by adding unscheduled patients that day, ideally by an assistant or nurse rather than the physician. For patients who need procedures or labs done urgently, the patients could be scheduled earlier rather than a typical practice of adding them at the end of the day. For example, a critically ill patient could be prioritized to be included in the schedule as soon as they arrive. As another example, a patient with acute knee pain could be scheduled at 1 p.m. in order to allow a same-day test, initiate treatment, and wait for a phone call to come in from a specialist before the end of the day. Alternatively, patients who are not scheduled who want same-day appointments can be delayed until the next day or later if a day is particularly busy or challenging. Infection control can be increased by shifting around the order of patients to avoid having an immune-compromised patient in the waiting room at the same time as a patient with chicken pox. New patients or particularly complex patients can be scheduled on days with lighter schedules or in the afternoon. Patients who have a history of being late or no-shows can be scheduled at the end of the day to avoid waiting and then rushing. Particularly light schedules can be optimized by moving patients to other days or into a tighter block to reduce waiting between patients.

3.A.2 Supporting remembering what to do during the patient visit: All of the SMEs described a need to better support remembering what to do during a patient visit, similar to having a post-it note on the top of a paper chart file folder for a patient or underlining, circling, or highlighting important information on a paper chart. The time when a decision is made to remember to do something during the visit could occur anytime immediately following the prior visit until the night before or the morning of the actual visit. Examples of the type of information to be remembered ranged widely, including updating patients about clinical information, such as significant findings from a consultant, a change to a treatment plan, a lab result, needing a vaccination, or preventive action done during the visit like, for example, a foot exam for a diabetic. Some wanted to remember particular areas to focus on during the physical exam, such as the left side.

Another descriptive example was a patient who was challenging to diagnose at the prior visit. Following the visit, the physician had searched and discovered that in the Balkans in Bosnia, wild boars mixed with domestic pigs, resulting in resurgence in endemic trichinosis. During the next visit, he decided to ask the patient about their country of origin to see if this might be the diagnosis. The physician used a flag in an inbox program for months as a reminder since there was no available support in the EHR, and he did not routinely read the last note from a prior visit before patient visits.

In addition, a few SMEs suggested supporting remembering information to support building and maintaining a relationship with patients with less direct clinical relevance, such as asking about “a fishing trip that was mentioned at the last visit,” mentioning “to say hello to a parent” that is also treated by the same physician, or emphasizing the importance of adhering to a particular aspect of a treatment plan for which the patient previously has deviated, such as cutting pills in half to save money. There was strong consensus that these reminders should not be permanently

maintained in the formal record, as the purpose was to support short-term memory of what to do during the visit, which was already officially documented. Suggestions for how to meet this need included reminders that were displayed when a chart was opened, flags on labs, annotations to overviews of patients indicating a reminder that could be viewed upon roll-over, personal notes when a chart is opened, time-based reminders that come into an inbox, and annotations to prior or scheduled vaccinations. It is important to note that all these features should be "displayed on demand" by a user.

3.A.3 Cognitive "warm-up" support: Immediately prior to entering the patient's room with a paper-based chart, physicians typically have a summary sheet outside the door which could be reviewed. Information could include the patient's full name and nickname (which several SMEs mentioned was critical for patient rapport – not just the last name), the patient's vital signs taken during check-in, information brought in by the patient such as blood pressure data on a home monitoring device, information filled out by the patient in the waiting room on forms, the medication list, or other relevant information. Particularly when the computer was located in the patient room, this "warm-up" was not well-supported with the EHR. Some SMEs expressed a desire to have a mobile device which was always logged in to support this, one SME went to his personal office before every patient visit in order to log in to get this information although he felt that it was inefficient, and some SMEs still used paper printed from the EHR for this purpose. Several SMEs used the computer extensively during the exam, and would be willing to look at this kind of summary "warm up" information after entering the room, and even, in some cases, sharing the screen with the patient so that they could view the information at the same time. SMEs suggested this information would be helpful for this purpose on a single display for each patient: full name, date of birth, current diagnosis, current medications, recent visit summary, problem list, allergy, past medical history, and new notifications. SMEs described the critical role of having patient narratives as free text, particularly for historical information, in order to capture subtle yet important distinctions about when events occurred and the level of certainty about the events.

B. During the patient visit

In Figure 4, the process steps related to activities occurring with the EHR during the visit are shown. These are:

- Check in patient, obtain vital signs and chief complaint from patient,
- "Warm up" and remember pertinent information,
- Collect medication reconciliation data and review of systems data,
- Get history, signs and symptoms, review of systems, make working or presumptive diagnosis,
- Examine patient, physical,
- Form initial treatment plan,
- Review chart/research guidelines, informal consult,
- Initiate intent to order medications, procedures, labs, consults,
- Verify medications and allergies,
- Pick diagnostic (ICD-9-CM, ICD-10-CM) and procedure (CPT) codes, verify insurance, investigate requirement for public reporting,
- Verify dosage for some medications,
- Explicit Orders: medications, procedures, labs, imaging, consults/referral,

- Clinical Procedure,
- Patient education,
- Give patient summary,
- Physician and/or others tells/reviews patient initial assessment, plan, and “to do” activities, motivates following plan,
- Document relevant history, physical, assessment, plan,
- Documentation to support billing,
- Document medications reconciled, and
- Documentation for others (legal, research, compliance, MU).

Several of the steps described are highly similar across the SMEs, presumably due to influences from regulatory aspects: what occurs during the check-in process, verifying medications and allergies prior to ordering medications, verifying Review of Systems data, assigning a diagnosis, patient education, and giving patient’s summary information. There was greater variability in terms of what elements of the workflow were shared across multiple roles. The SMEs described different approaches to doing tasks, shared across personnel such as a primary care or specialist physician, physician assistant, nurse practitioner, intake nurse, nurse educator, case manager, medical assistant (clerk), and even in some cases the patient or family member when paper forms were used. Variation was described in by typically:

- Collects the Review of Systems data for the appropriate body functions,
- Enters the information into the EHR,
- Determines the diagnostic (ICD-9-CM, ICD-10-CM) and procedure (CPT) codes,
- Determines whether insurance covers particular activities,
- Verifies the accuracy of relevant medication types and dosages, and
- Makes changes to the schedule during the day.

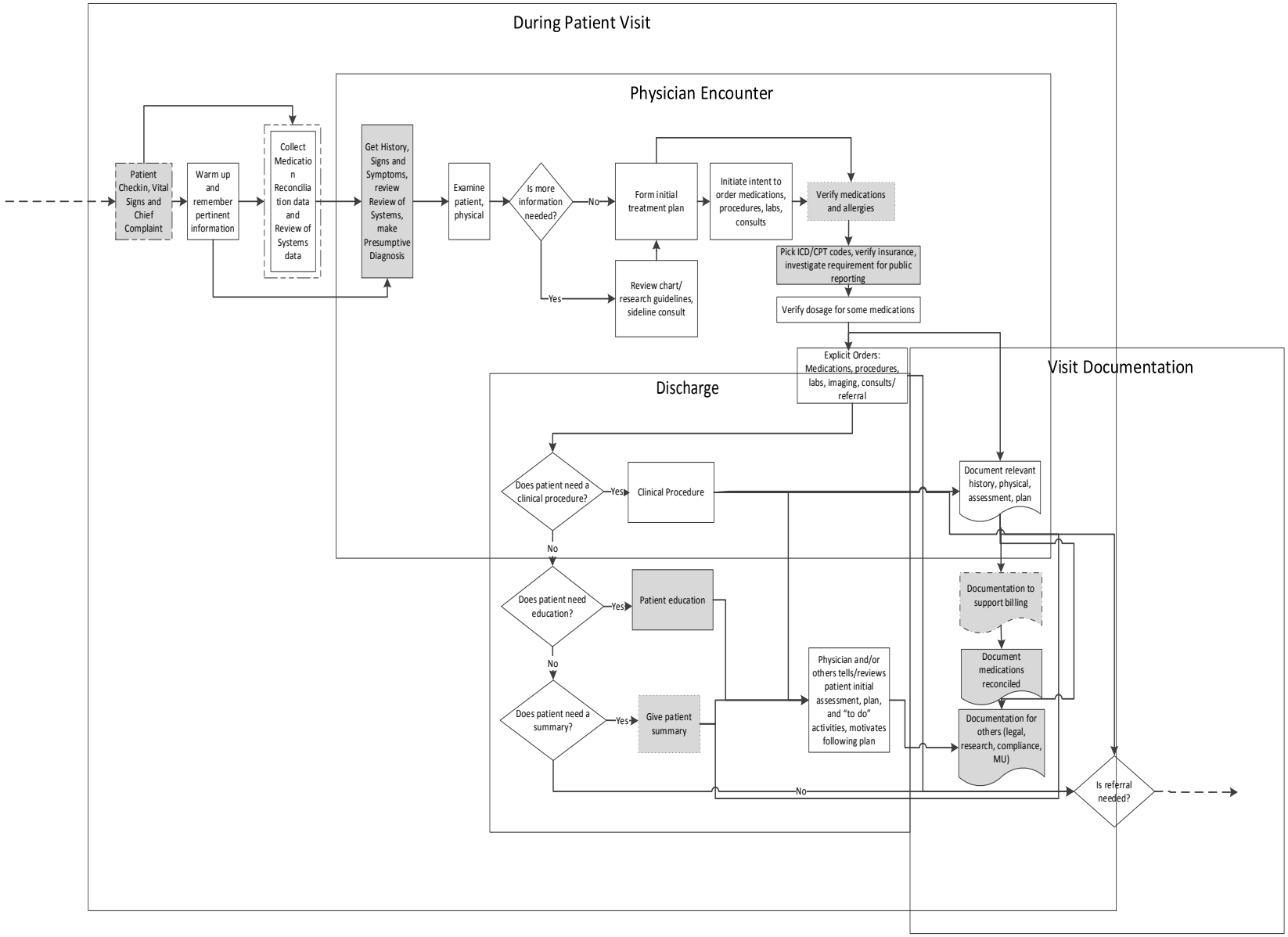

Figure 4. Process map for activities conducted during a returning patient visit with the EHR

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Opportunities for providing support via the EHR for cognitively challenging tasks suggested by the SMEs are:

3.B.1 Managing patient flow

SMEs described that the natural affordance of paper charts in slots outside exam rooms as letting them know whether they can slow down or need to speed up visits based upon how long the queue is of patients waiting for them, and would like this functionality provided in the EHR. In some cases, this functionality exists, but users find it difficult to use without targeted training and support in implementing the feature. They stated that they would quickly interact with waiting patients to let them know they were running behind and to expect a delay in care when there were four or more patients waiting.

3.B.2 Identifying time-critical notifications

All of the SMEs described an "inbox" metaphor in their EHRs where time-critical information is grouped together with less time-critical information. Typically, none of the SMEs looked at their inbox after entering the room for the first patient visit until after the final patient visit was completed, unless possibly during a lunch break. SMEs mentioned that no one can see how full the inbox is when they send a message to it, unlike what occurs when a note is placed on a pile of existing requests at a desk or on an empty chair. With paper-based requests, it is fairly easy to determine the size of a stack, the messiness of the stack, whether or not the request has been moved from one place to another, indicating that it has been noticed, and which requests are most recent (or urgent if reordered at a later time) based upon what is on top. SMEs described four instances in the last month where information relevant to that day's visit was viewed after the visit had been completed, including a patient who requested disability paperwork filled out which could have been done during that day's visit along with addressing his chief complaint and performing health maintenance activities, but ended up requiring scheduling an additional appointment, and therefore an additional payment, a week later to accomplish it. Similar issues have been reported in the literature.[lii] Although there were no obvious solutions, characteristics of desired solutions could be to: 1) abandon the inbox metaphor completely, 2) reduce information sent to the inbox (e.g., send notifications about updated labs to an area dedicated to showing lab information with highlighted new information for groups of patients), 3) segregate types of information channeled to the inbox (e.g., time-critical information for that day displayed separately from other information), and 4) eliminate/group/thread messages containing redundant information or updates about the information.

3.B.3 Redacting and summarizing laboratory results

Most SMEs reported great need for single summary page for every patient that would include recent lab tests in a summary format; in addition to the most recent lab results, it is important to include in the summary pertinent historical lab data relevant to the patient's diagnosis.

Some of the users informally create their own, typically with handwritten notes added to a printout from the EHR. Physicians who specialized in geriatrics wanted certain conditions of the patient such as diabetes, hypertension, heart disease, smoking, emphysema, pulmonary disease, atrial fibrillation, cancer, drugs that require close monitoring like warfarin, pain medications like opiates, who they live with, and key issues. SMEs described that the medical assistants download

recent results from a separate system and redact them for their physicians into the chart. The information is entered into a template for system assessments in order to support users' quickly scanning the information, and will fit onto a single page where discharge instructions are printed describing the regimen, emergency instructions for the patient, special instructions, and sub-categorized information within these areas. It would be helpful if the EHR would similarly redact information onto a summary display as well as support having identical formats from different companies, searching within and across documents, and adding free text commentary directly onto the summarized information.

In addition, an important critically needed feature is one to support tracking lab results longitudinally across time, including grouping related labs and annotations. These results could be searched by date done, date accessed, whether they were abnormal, or by key phrases in the annotations or progress notes.

3.B.4 Drafting predicted orders

Several physicians described that they would like the capability to initiate without fully committing yet to orders that would likely be decided upon and/or explicitly ordered during the visit. Examples include lab orders that are typically ordered on a routine basis for a diabetic patient, a colonoscopy which is indicated to be due, and a pneumonia vaccine which is assumed to be needed based upon the age of the patient. Several SMEs mentioned that there are often changes to predictions about what orders will be made based upon information obtained from the patient, such as providing a different date for the last colonoscopy than was documented in the EHR. Many physicians felt like they were on the verge of doing more orders (medications, labs, procedures, imaging) during the visit if the process could be made more efficient, and one approach to improving efficiency is to batch modify "draft orders" to change them to "actual orders" during a visit. It would also be important in the workflow to purposely delay ordering particular draft orders which require additional information, such as information from a radiologist about which imaging test is best to order, information about whether a procedure is covered by the patient's insurance, or information about which pharmacy is used by the patient prior to ordering.

3.B.5 Transferring initiated tasks to another to complete

All SMEs believed that physicians were typically the bottleneck in the process flow in ambulatory care settings. All of them felt that there were aspects of how the EHRs were designed that increased the time spent during this bottleneck which had the potential for unintended consequences for patient care. For example, there could be a lower quality of care due to less time to spend interacting with the patient and lower reimbursement because visits were somewhat longer or fewer could be scheduled in a day. In several cases, examples of superior support for workflow with paper-based charts were described. Many of these examples had the common theme of transferring portions of tasks under the responsibility of physicians in order to make the overall process more efficient, such as:

- **Preparing for visit:** A medical assistant could pull together data dispersed throughout the chart in a summarized, systematic format for elements which are commonly needed based upon the disease. For example, diabetic patients could have their last few A1C readings, blood pressure readings, and weight summarized. The patient-specific goals that were provided at the last visit could be included, such as a diet and exercise plan or a target weight to achieve.
- **Scheduling:** A medical assistant or nurse could review and modify a schedule to add in unscheduled patients, avoid having an immune-compromised patient in the waiting room

at the same time as a patient with an infectious disease, in response to information that a patient is running late in arriving to the appointment, or other factors.

- **Review of systems data collection:** Medical assistants, intake nurses, nurse practitioners, or physician assistants could collect and type in some Review of Systems data for the appropriate body functions collected from the patient or caregiver which are then reviewed by physicians for accuracy with the patient.
- **Verifying medication reconciliation data:** Medical assistants, intake nurses, nurse practitioners, physician assistants, or case managers could verify and reconcile lists of medications from various sources with the patient and caregiver, potentially also including filling the pill box and verifying that labels brought in on home medication bottles match the documented medications in the EHR.
- **Screening questions/reminders:** An intake nurse could ask patient screening questions and resolve and document clinical reminders for preventive care activities prior to or following a patient visit with the physician.
- **Print vital signs:** Intake nurses or medical assistants could print vital sign information and leave it outside the door of an exam room to make it easier for physicians to quickly read and interpret this information prior to walking into a room.
- **Draft progress notes:** Commensurate with their training and license, clinicians other than the physician could draft progress note assessments, conduct portions of a physical exam (e.g., a diabetic's foot exam), and collect historical information from the patient.
- **Draft orders:** Resident physicians, nurse practitioners, physician assistants, case managers, nurses, or medical assistants could draft predicted orders for routine situations, which are then verified by a physician prior to becoming an explicit order.
- **Patient summary/education**: Case managers or nurses can provide patient summaries and education to patients that are initiated by a physician or known to be required by standard protocols.
- **Billing codes:** Scribes, medical assistants, or specialized information management personnel could assign diagnostic (ICD-9-CM, ICD-10-CM) and procedure (CPT) codes to a visit and prompt physicians to add sufficient documentation to justify reimbursement.

3.B.6 Supporting dropping or delaying tasks under high workload conditions

Based upon our discussions with SMEs, tasks are sometimes dropped or delayed when there is extreme time pressure due to high workload or one patient taking a longer time than scheduled. Therefore, it is suggested that the EHR be designed to be robust to dropping or delaying these tasks. Likely this will require "decoupling" tasks that have been merged to simplify the interface interaction, but create issues with workflow during deviations from a routine sequence. Tasks that were identified by our SMEs as on the potential cutting block during high workload conditions for some patients include:

- Deal with more than one issue,
- Screening/preventive,
- Conversation for rapport,
- Detailed physical exam,

- Blood pressure reading,
- Review all new results,
- Orders during visit,
- Patient paperwork,
- Ensure correct medication brand, pharmacy, or insurance coverage,
- Education,
- Set wellness goals,
- Verify patient knows what to do next,
- Clinical reminders/alerts, and
- Documentation.

3.B.I Physician encounter

The definition for *clinical encounter* from ASTM E1384-02a - *Standard Guide for Content and Structure of the Electronic Health Record* is: "(1) an instance of direct provider/practitioner to patient interaction, regardless of the setting, between a patient and a practitioner vested with primary responsibility for diagnosing, evaluating or treating the patient's condition, or both, or providing social worker services.
(2) A contact between a patient and a practitioner who has primary responsibility for assessing and treating the patient at a given contact, exercising independent judgment."

In Figure 5, the process steps related to activities occurring with the EHR during a physician encounter are shown. These are:

- Get history, signs and symptoms, review of systems, make working or presumptive diagnosis,
- Examine patient, physical,
- Form initial treatment plan,
- Review chart/research guidelines, sideline consult,
- Initiate intent to order medications, procedures, labs, consults,
- Verify medications and allergies,
- Pick diagnostic (ICD-9-CM, ICD-10-CM) and procedure (CPT) codes, verify insurance, investigate requirement for public reporting,
- Verify dosage for some medications,
- Explicit Orders: Medications, procedures, labs, imaging, consults/referral,
- Clinical Procedure, and
- Document relevant history, physical, assessment, plan.

The steps described had striking similarity across the SMEs. Nevertheless, there appeared to be high variation in whether and how the EHR was used during this period, how extensive each of

the activities typically were for each SME, different based upon the type of patient, how complex the patient was, context of how busy the day was, and other factors.

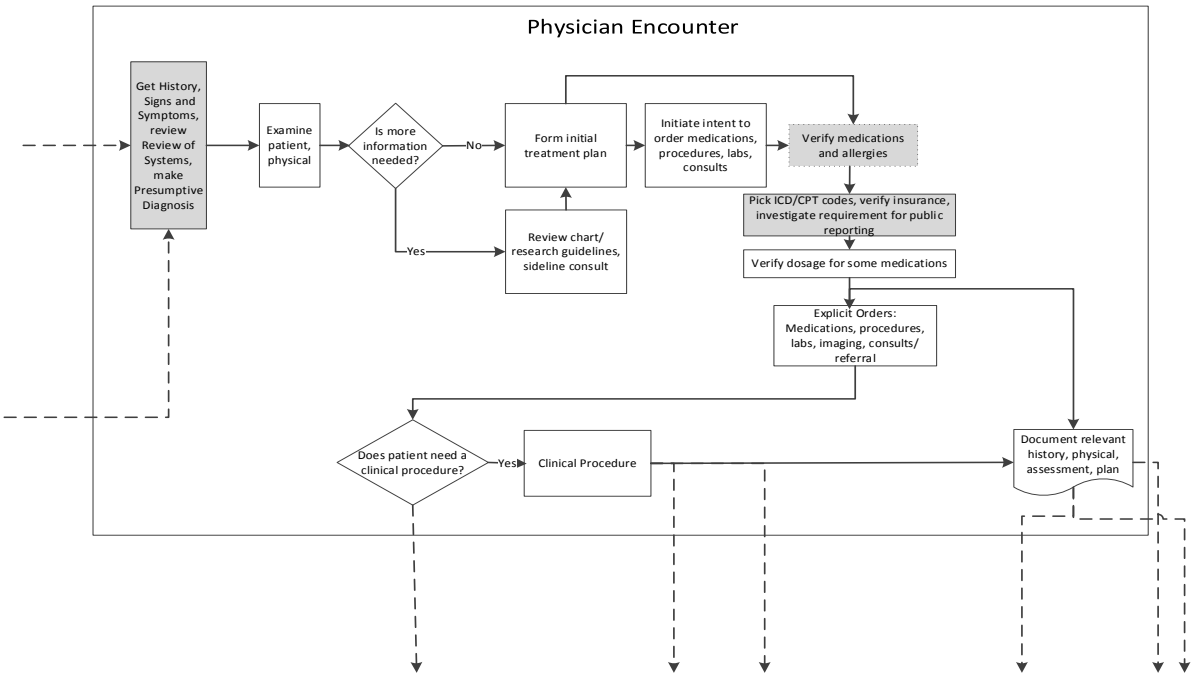

Figure 5. Process map for activities conducted during a physician encounter with the EHR

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Opportunities for providing support via the EHR for cognitively challenging tasks suggested by the SMEs are:

a. **Supporting established diagnosis-based workflow**: Several SMEs mentioned that elements of the provider exam were predictable based upon established diagnostic information. One SME differentiated between diagnoses which were working diagnoses (not yet confirmed or a broader category than would be achieved later), established, and new problems. For established diagnoses, templates could be generated to guide information typed in by the medical assistants that would impact on where the physical assessment was focused. It is important to note that few patients have a single diagnosis; it is typical to have complex combinations of multiple diseases, and these patients account for the majority of healthcare expenditures.[liii] One SME emphasized that information generated by medical assistants would need to be distinguished from information generated by providers with more medical training (physicians, nurse practitioners, physician assistants).

b. **Supporting moving from working diagnoses to formal diagnoses**: Every SME expressed enormous frustration that most elements of their EHRs assumed that a diagnosis was already established at a detailed level. The consensus was that problem lists were not accurate based upon extensive workarounds, not having the information at the time it was required to be entered, or difficulties in modifying existing diagnoses once

selected. For determining new diagnoses, the desired workflow was to start with less detailed working diagnoses based upon observable signs and symptoms, and then confirm or disconfirm possible diagnoses via a differential diagnosis process, and then progressively get more detailed in the diagnosis as more information was available. For example, a patient might start with a symptom of a cough at which time "cough" is the most appropriate description of the signs and symptoms focused on during a diagnostic process before a definitive diagnosis is known. The physician might then suspect that the patient has tuberculosis along with one or two other possible explanations for the cough. While labs are being ordered to confirm or disconfirm tuberculosis, the patient might be proactively treated as if he has tuberculosis in order to start treatment earlier, as well as to protect other patients and the public. At the end, a detailed ICD-9 diagnostic code may be selected after most or all of the evidence has been collected and analyzed. Any interaction with the EHR which was based upon a detailed ICD-9 code, such as writing a progress note, writing an order, and documentation to support billing, was frustrating in this situation. Workarounds (such as selecting a generic "unspecified" ICD-9 code or an alternative ICD-9 code which was unlikely) were reported in order to do the activities which were considered necessary to establish the accurate detailed diagnosis. Allowing "unknown" to be selected as a diagnosis in order to perform activities in the EHR would be ideal from a physician's perspective. One paper suggests having the ability to label diagnoses with certainty information such as active or resolved and which department or clinician entered the diagnosis.[liv] It is important to update the diagnostic information in a timely fashion to meet reimbursement needs, document known information about diagnoses, report relevant quality metrics, and conduct research based upon cohorts of patients with the same diagnosis.

c. **Supporting reviewing changes to medications**: High variability was reported regarding the process for medication reconciliation. In some cases, there was a compliance mindset of "checking the box" with minimal effort to verify that medications were correct. In some cases, physicians believed that they were only responsible for verifying medications which they personally had ordered. In some cases, some described how others expended significant time and effort in reconciling medications, including going through each and every medication physically with bottles brought in by the patient and even going so far as to personally place pills in daily pill boxes for patients to ensure that they are correct. Because medication reconciliation is required by The Joint Commission, there was a step described in the process to meet that requirement. In addition, however, some SMEs described additional informal "double-checks" at various points during the provider exam. Generally, this verification step was not done with all medications, but only those medications which were new, problematic, changing, or particularly high-risk and related to the reason for the visit. Support for this verification step could be incorporated into the EHR by displaying medication lists and in particular highlighting changes to lists over time for types of medication and dosages of medication, including what changes will occur once drafted medication orders are explicitly executed. In order to support the detection of side effects, this information could be viewed against other data, such as weight or blood pressure.

3.B.II Discharge

In Figure 6, the process steps related to activities occurring with the EHR during discharge are shown. These are

- Explicit Orders: Medications, procedures, labs, imaging, consult/referral,
- Clinical Procedure,
- Give patient summary, and
- Physician and/or others tells/reviews patient initial assessment, plan, and "to do" activities, motivates following plan.

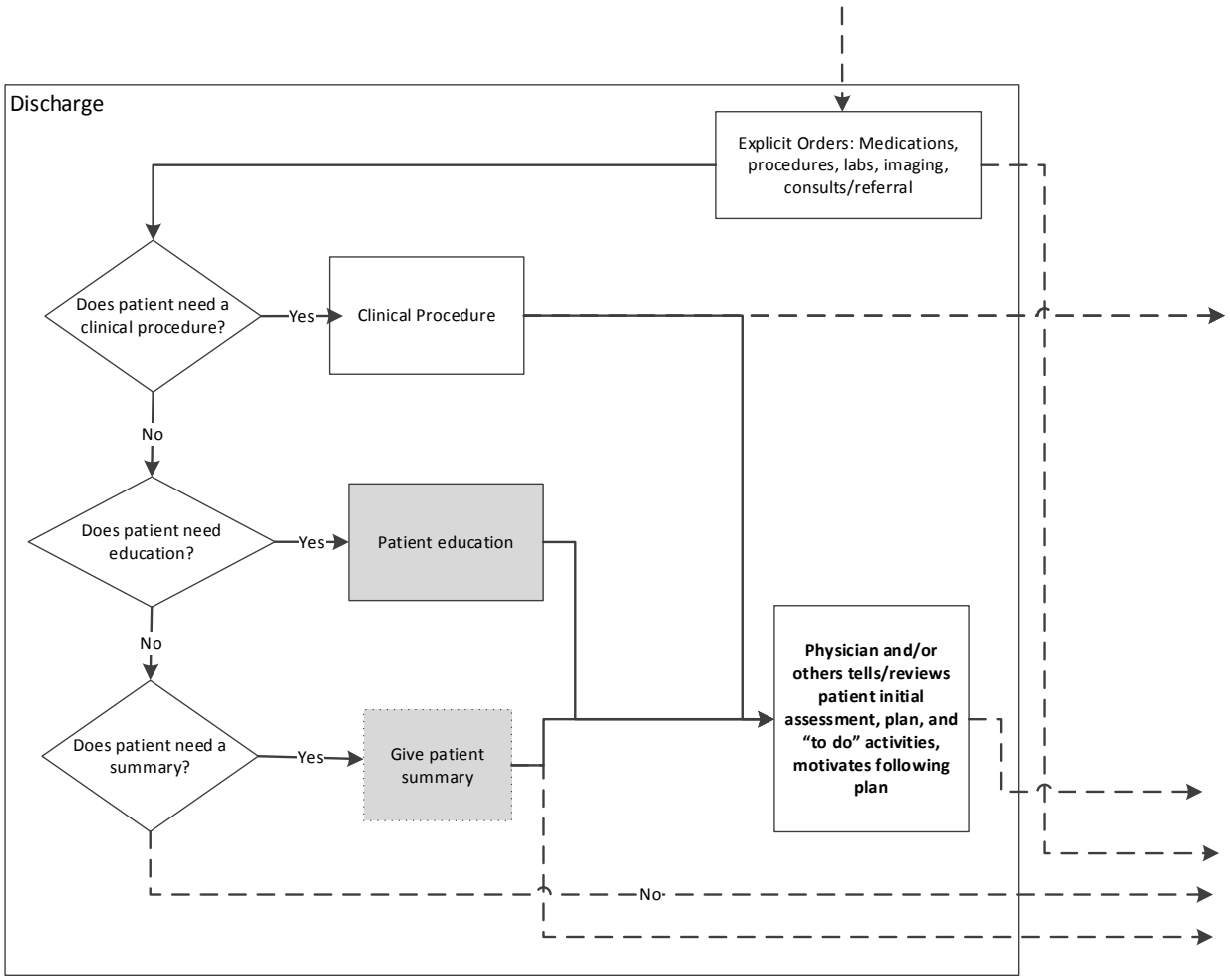

Figure 6. Process map for activities conducted during discharge with the EHR

We have further provided diagrams for the workflow of explicit orders in labs, imaging, medication, consult in figures 6a, 6b, 6c, and 6d respectively.

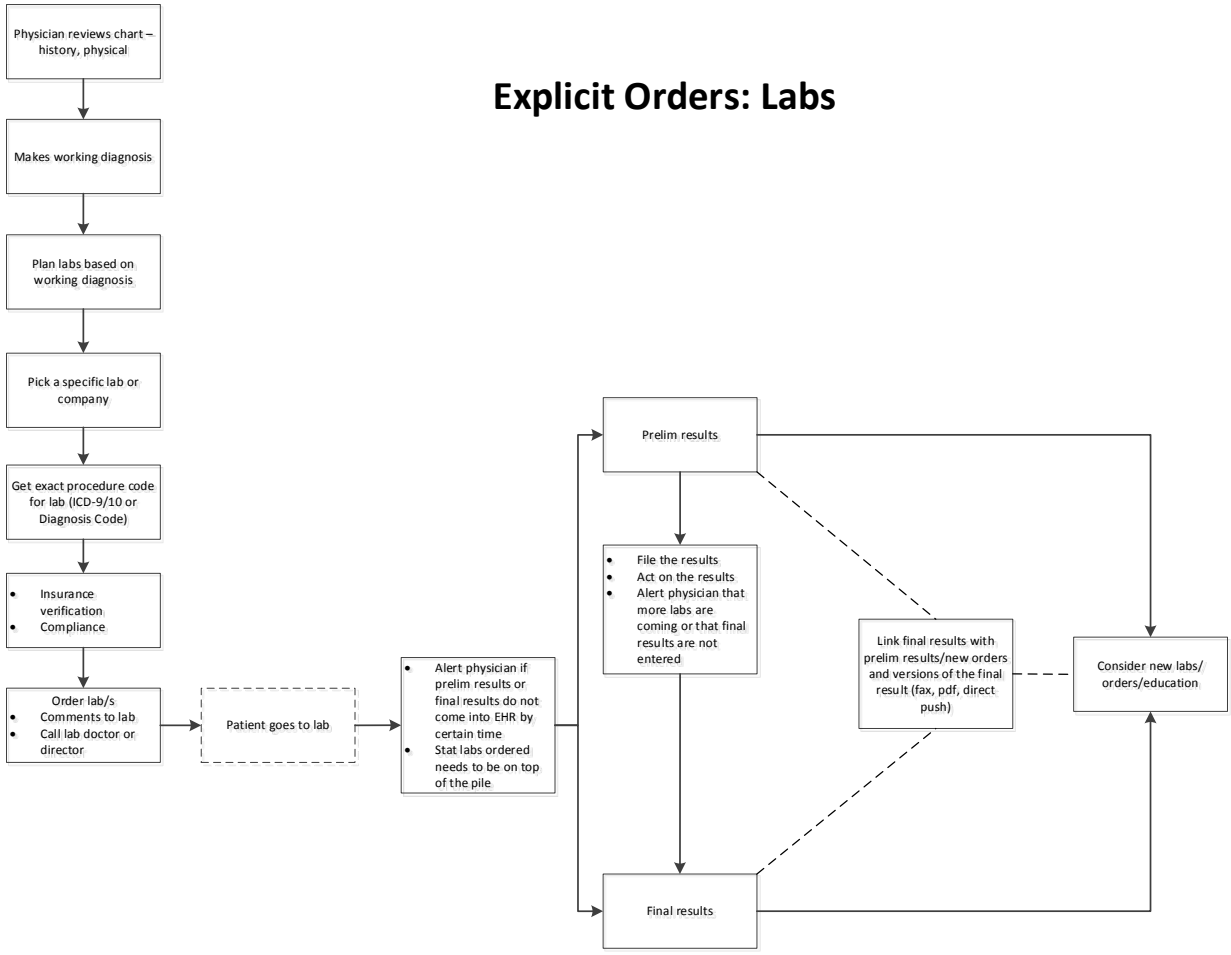

Figure 6a: Workflow of Explicit Orders: Labs

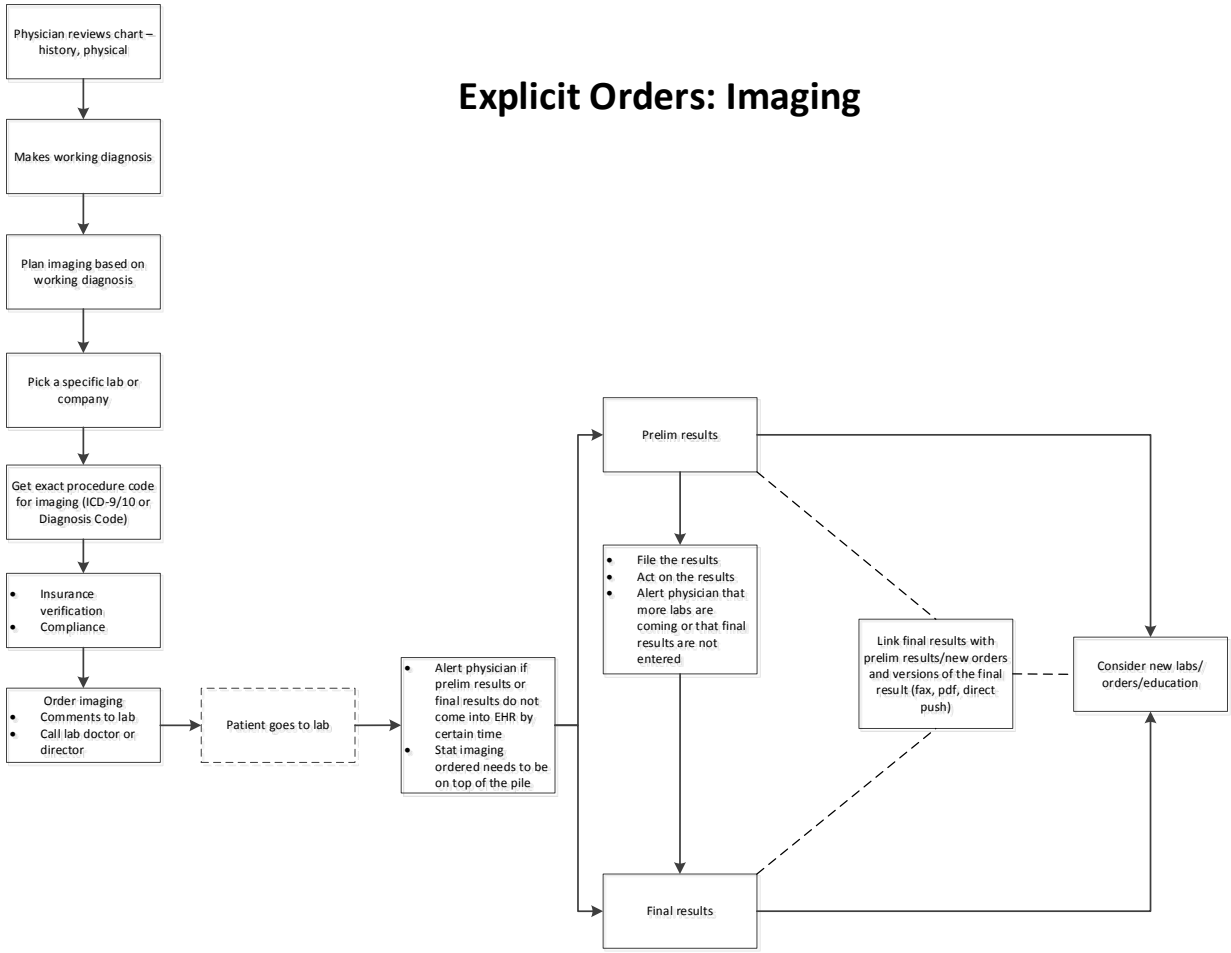

Figure 6b: Workflow of Explicit Orders: Imaging

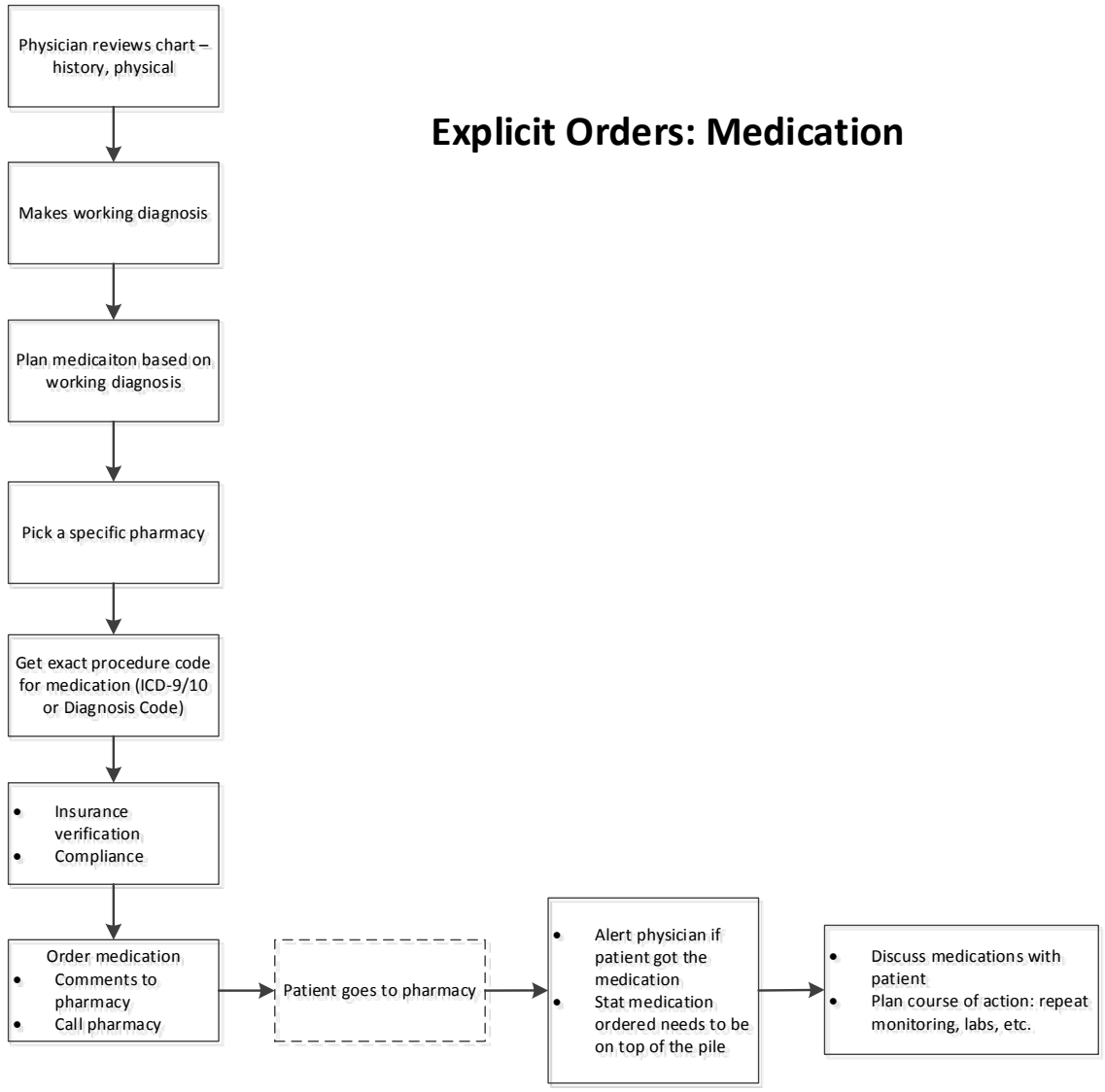

Figure 6c: Workflow of Explicit Orders: Medication

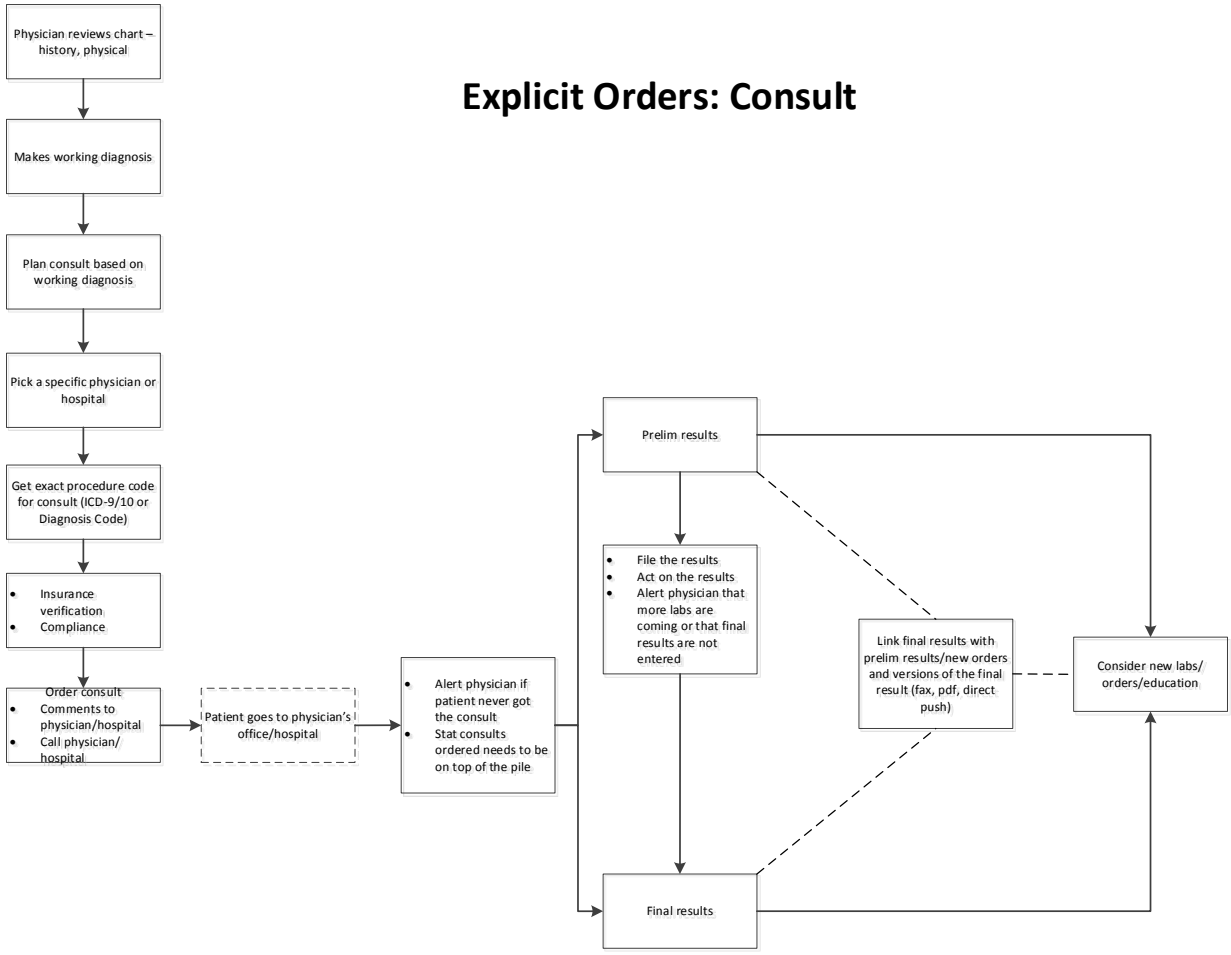

Figure 6d: Workflow of Explicit Orders: Consult

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Opportunities for providing support via the EHR for cognitively challenging tasks suggested by the SMEs are:

a. **One-page patient summary**: Several SMEs described that the required After-Visit Summaries for compliance purposes were too long, generally about ten pages. In addition, elements included in the after-visit summary handed to patients could be inappropriate. For example, infants are not likely to need to attend a tobacco cessation program, yet reminders like this are sometimes required to be included in a printed summary in order to be compliant with requirements from accrediting organizations. In addition, required terms can be confusing to patients who had diagnoses explained to them more in "lay terms" and then handed information with clinical terms. For example, a patient might have been told that "A young and healthy kidney has 80 mL -100 mL of cleaning capacity, yours is now 42 mL, and dialysis will be required at 15, normally by age 60." Then on the after-visit summary, this information is documented as "ICD-9-CM

585.3 Chronic Kidney Disease Stage III (moderate)," which they might have a difficult time realizing is the same as what was explained to them. Although there was some variation in what SMEs described they needed specifically, generally all of them agreed that a one-page summary with the required information attached would be an improvement. Suggestions for what information to include in a one-page summary are: 1) what is required to do today, 2) what was ordered, 3) what medications are new or changed, including what has been stopped and what to continue taking at home, 4) information about when the next appointment is, 5) testing/referrals between now and the next appointment, and 6) instructions, including what to bring to the next appointment.

b. **Supporting handing off patient education**: Patient education can be initiated by the physician and then handed off to others, such as the intake nurse, case manager, physician assistant, or nurse practitioner. In some cases, there are specialized roles, such as a diabetic nurse educator, for specific educational purposes. Current means of supporting this handoff such as clinical reminders that are required for all diabetic patients are not fully effective at capturing patient-specific information on what to focus on. Some paper-based mechanisms are still usefully employed, such as handing education packets of brochures on particular topics with handwritten notes at the top for the person who accepts the handoff. Supporting this process with less reliance on the patient and paper-based mechanisms via the EHR would be useful. Understanding what motivates the patient to invest energy into improving health is a particularly important aspect of patient education, and supporting physicians sharing this information, such as wanting to be able to spend time with grandchildren without being intubated due to overexertion, would be helpful in making education more patient-centered.

3.B.III Documentation

In Figure 7, the process steps related to activities occurring with the EHR during documentation are shown. These activities document:

- Relevant history, physical, assessment, plan,
- Support billing,
- That medications were appropriately reconciled,
- Requirements that must be met for others, such as legal, research, compliance, and Meaningful Use requirements, and
- Consult requests or a follow-up letter after a consult to relevant providers.

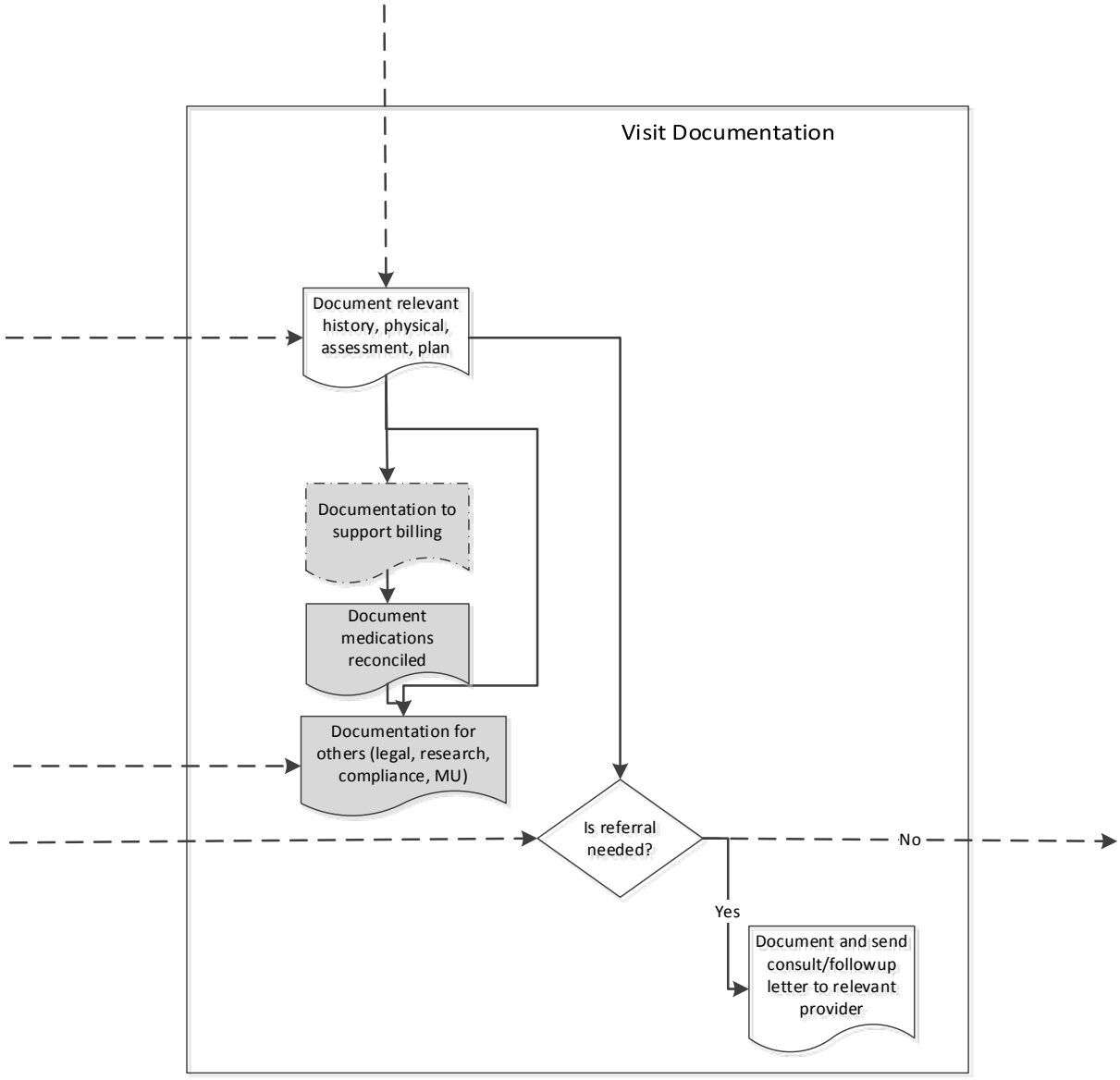

Figure 7. Process map for activities conducted during documentation with the EHR

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Opportunities for providing support via the EHR for cognitively challenging tasks suggested by the SMEs are:

a. Reducing time spent on documentation of provided care

All of the SMEs reported immense frustration with reduced productivity (fewer patients scheduled in a day) or reduced personal time due to an increased time to document care. One of the SMEs changed organizations in the hopes of having more time with patients and less doing documentation from a combination of organizational expectations for how many patients to see a day as well as the EHR that was used. Some physicians had made the decision to work solely in

hospital settings and no longer in ambulatory care in order to avoid the increased documentation burden when the EHR was installed. There was consensus that a positive feature of the EHR was an increased ability to document progress notes from home or other locations. The risks of failing to return a patient's chart in a timely fashion if brought home to document care were considered too great with a paper-based system, and therefore most of the SMEs chose to stay in the office to conduct documentation for patients seen that day for an hour or more. With the introduction of the EHR, all of the SMEs reported an ability to leave the office earlier but an increase in time spent doing documentation from home at night.

Few of the SMEs did any documentation in the EHR during the visit, primarily because the perception was that interacting with the human-computer interface reduced the ability to effectively communicate with the patient. Communicating with the patient was considered critical for eliciting and interpreting historical information from the patient, understanding concerns for diagnosis, understanding barriers to implementing a proposed treatment plan, building and maintaining a rapport, and motivating adherence to a treatment plan. Communication that was done with the physician's back to the patient or with the physician's eye gaze averted to the computer was judged to be sub-optimal for these purposes. Another SME explained that "If while creating the note things occur to me that I want to find out I can do that, if I had to finish the note, say goodbye, and move on, then there would be less flexibility about thinking and looking into the problems." One physician described that he does all of his documentation after the visit, but that he wished that he could do it during the visit. The benefits of doing documentation real-time with the patient would include avoiding to ask them something that is needed for an order, having the opportunity to review the documentation with the patient in order to detect and correct mistakes in interpretation, wanting to show patients lab results and imaging studies on the computer, having a more efficient documentation process that relies less on memory which is impacted by seeing other patients prior to documentation, and having a faster and more efficient process.

Suggestions to increase the acceptability of doing some or all documentation during the patient visit were having a continuous login or otherwise increase the efficiency of the login process, being able to share the screen with a patient to show lab results or other results together, being able to position the body towards the patient by having a mobile device, being able to benefit real-time from decision support which impacted the steps which the patient had to do next, and being able to provide the patient with a printed summary of what was documented during the visit to remind them of what to do next and how to do it. Making the process of reviewing results more efficient and having the ability to lower the required health literacy level needed to interpret the results were opportunities identified by several SMEs. For example, having results clearly marked as regular as opposed to abnormal, displaying reference ranges, and using less clinical terms such as "blood sugar" would help when sharing the screen with patients without medical training. Finally, eliminating or greatly reducing requirements to interact real-time with the EHR for longer-term goals such as entering detailed data to justify that a procedure is necessary for reimbursement would increase the willingness to begin a progress note during the visit.

Requirements to enter data as structured text were viewed as one of the top contributors to an increase in the time spent documenting progress notes. Several physicians felt strongly that there were too many "clicks" required to enter information, both because of poor usability of the interface as well as too much emphasis on categorizing information into structured elements. In comparison with a paper-based system, clicking through an interface to document information and categorizing information into structured elements are primarily new tasks which largely did not exist in the previous systems. In situations where there were paper forms where selections were made, there were fewer options for structured data. For example, there might be 3 options

on a paper form but 300 options in an EHR for categorizing information. In some cases, with paper-based systems, other personnel would provide additional data when categorizing documentation on paperwork into billing codes or other structured data, but this work was invisible to physicians.

There was large variation in the preferences and experiences of the SMEs with strategies to make documentation more efficient. One SME reported that all of her progress notes were created using templates, and felt that was a good strategy when there were clear expectations about what information should be recorded in what order. She felt that this aided efficiency and standardization across providers in her small practice. Other SMEs reported that templates encouraged "garbage in garbage out," documentation which was less reliable than with paper-based systems, particularly for the information documented by intake nurses and medical assistants using templates. Another SME described frustration with a template that placed a large amount of auto-generated text in the note when clicking "denies to all" to meet billing and legal requirements, creating a longer note than is used when "only the positive findings" were desired to be documented for clinical needs. He described that it was difficult to understand information generated in this way when the note has "cough denied, temperature denied" etc. In one situation, he was not able to locate in the note the information which he considered critical for diagnosis that the patient was not urinating every night, even though he looked explicitly for it.

Several of the SMEs had attempted and then abandoned strategies to increase the efficiency of documentation. One SME reported that copying and pasting and "smart text" where typing commands generate auto-text had a "vigilance problem." The issue was that it would be too easy to put the wrong or outdated information in or in the wrong place and not detect it, and then someone later, including himself, could act on it not realizing that it was incorrect. One physician described an attempt to use automated speech recognition for dictation for a patient with scleritis, which is inflammation of the white of the eye. He stopped using the software when what was documented in the note was "squirrel actress." Another SME described that colleagues relied upon medical assistants to draft the note and then completed it, but they did not like that approach because it was too tempting to rely upon what was typed without reviewing it, and he felt the medical knowledge level was not high enough for this task. One SME described a reluctance to use any scribe, including a medical student, because the risk would be too high of misunderstanding and thus not correctly documenting the historical information, diagnosis, and treatment plan. This was particularly problematic if the physician had information from prior visits which contributed to these elements which were not discussed in detail during the visit.

b. Supporting different views of a progress note based upon role

One potential design opportunity would be to change the view of the progress note based upon a particular role. For example, the progress note for a primary care physician would have a different view from a specialist such as a urologist physician, who might not need to see all of the information displayed to the primary care physician. Similarly, the view of the note for primary care providers could differ from the view of a billing and coding specialist. When multiple views are provided, it is recommended that physicians be able to view the note from the perspective of other roles on demand in order to ensure that they are meeting the needs of others with their documentation. All SMEs described frustration with requirements to enter information into progress notes which match the types of codes which were applied to the notes in order to have sufficient justification to receive reimbursement for services. Although all of the SMEs acknowledged the central importance of receiving reimbursement in order to function as a business, this information was often not important for clinical needs.

Similarly, all of the SMEs described that progress notes are accessed for a wide variety of purposes, including documenting clinical needs for themselves for the next time they see the patient, documenting information for colleagues who may treat the patient in the same role, documenting information for team members who treat the patient in different roles (e.g., case manager, intake nurse), and documenting information for research and quality improvement purposes.

c. Distinguishing new documentation from copied information

A well-known and frequent workaround with all EHRs is to copy and paste information. There are three known variations: 1) to copy from one progress note from a prior visit for the current visit which serves as a first draft that is then revised to increase the efficiency of documentation, increase coverage, and reduce the likelihood of having contradictory information across notes; 2) to copy information into a temporary repository, such as Notepad, in order to view it in parallel with another tab, system, or time period in order to remember information; or 3) to copy information from one patient with a similar diagnosis to another, in order to have a working draft which is then revised to increase the efficiency of documentation and provide a template of what to include. A concern with this type of workaround is that billing should be done only for procedures that were done in that visit, and therefore it is important for coding and billing personnel to distinguish between old (copied) and new (typed) information. With one system, this need was met by copied text having a light gray background and that newly typed text in the progress note turned clear. Another solution is to have a template for notes which includes a section for “Historical Information.”

d. Supporting communication with specialist physicians about referrals and consultations

SMEs raised what they considered to be a critically important patient safety issue resulting from changes in documentation practices associated with changes from paper-based referrals to EHR-based referrals to specialist physicians. The pattern is to have much sparser to non-existent documentation or communication following a consultation by a specialist physician.

The SMEs created a fictional scenario in order to illustrate this issue.

With a paper-based system, the following would be typical of documentation by a specialist physician regarding a decision of whether to undergo a surgical procedure to replace a heart valve: "Bob Smith is a 17 year old who developed rheumatic fever 6 months ago. Please see his last note for a full description of his initial course of rheumatic fever. He was treated with antibiotics at that time, and remains on prophylactic antibiotics. His mitral valve was significantly damaged during the episode. He has severe mitral regurgitation due to significant damage to the anterior leaflet of the mitral valve. The mitral regurgitation vena contracta was 1 cm thru the anterior leaflet of the mitral valve. There is significant left atrial and left ventricular dilation. There is both systolic and diastolic left ventricular dilation. His shortening fraction is, however, normal. In addition, Bob has been complaining of shortness of breath with mild activity. He has no congestive heart failure on exam. His electrocardiogram shows left atrial and left ventricular enlargement but no strain patterns.” This case was presented at a surgical conference, and there was unanimous agreement that this patient should undergo an attempted repair or replacement of this valve. We reviewed this data with Dr. Jones, from pediatric cardiothoracic surgery who agreed the patients risk/benefit ratio favors surgical repair of this valve.

Following the implementation of an EHR at both the primary care physician's and the specialty physician's organizations, the following might be received from the specialist physician after seeing the patient via the EHR:

"1. Acute rheumatic endocarditis – 391.1 (Primary)
2. Rheumatic mitral insufficiency – 394.1, Moderate"

The SME's interpretation of how this situation occurs is that workflow for billing is prioritized over the workflow for informing the referring physician about the conclusion reached by the specialist physician. In other words, because billing required ICD-9 codes but a free-text narrative is not, sometimes the narratives are not written before the consult cycle is completed.

When the workflow support of an EHR supports timely billing, such as by automatically closing, locking, and signing an encounter based upon actions taken by a medical assistant, this situation is more likely to occur. When there is support for a free text narrative within the EHR, sometimes there is little support for formatting, spell checking, controlling page breaks or paragraph locations, or other layout elements. In some cases, the free text narrative information is not printed on the first page, but on subsequent pages and therefore can easily be missed by the receiving physician.

The SME described that this information would be uninformative as to whether the patient needed the surgical procedure ordered because the diagnoses were already known prior to the visit with the specialist. In this situation, the specialist physician would need to be contacted directly in order to better understand the assessment, or alternatively, the patient would accept the patient's or caregiver's interpretation of what was explained to them by the specialist during their visit with him or her.

The SMEs went on to describe workarounds employed to better support this process. With most EHRs, specialists can create a letter in a Word document and attach it electronically to the auto-generated text (the ICD-9 codes) and then someone in the primary care office would scan the word document into the EHR. In this case, the text could not be searched and often the scanned document would be placed in a place separate from other information received from specialists.

e. Supporting real-time documentation

The SMEs described three potential models relating to documentation during the actual patient visit:

1) No documentation during the visit. In this situation, the physician would review portions of the chart before seeing the patient, and do orders and documentation after the visit. In some cases, printed information would be taken into the room and handwritten notations would be made on the printout during the visit.

2) Draft documentation during the visit. In this situation, the physician would typically review new results with patient, do any simple orders during the visit, do consult requests that did not require extensive documentation, and create an initial draft of a note, typically employing a personal shorthand to increase efficiency and which would be replaced with a longer format after the visit.

3) Full integration of documentation during the visit. Only one SME used this approach. In this situation, he reviewed the last progress note immediately after greeting the patient (without showing this to the patient), entered data from the history real-time and from the physical immediately following the exam, did all orders and consult requests, finalized documentation which was done throughout the visit, signed the note, and then explained to the patient what steps to do next.

Several of the SMEs mentioned that they would like to pre-populate notes prior to the visit and enter information in abbreviated format into notes during the visit in order to aid writing the note at a later time. In addition, several SMEs mentioned that a mobile device or tablet would be preferable during the visit to improve patient-provider communication. It is possible that alternative functionality could be developed which avoids hard stops, alerts, verification steps, structured documentation, menu-driven interfaces, and typing to support real-time documentation in an efficient format. In this situation, "smart swipes" (as opposed to smart text) would not be used to auto-generate longer text, but instead to predict common interactions or things to remember to do later and to aid memory of what occurred at a later time when a progress note is modified and expanded. One SME mentioned that, rather than feeling uncomfortable dictating in front of the patient, it was actually preferred so that the patient could correct misinterpretations. Therefore, dictation that is partial and played back later could be incorporated into this workflow. Theoretically aspects of the patient encounter could be audio-taped to support this process as well, such as when the provider explains the next steps to be taken by a patient near the end of the visit.

f. Tracking scheduled consults and review of laboratory results

Several of the SMEs commented that it would be helpful to have support for a small-group practice or larger organization as a whole to ensure that intended actions to be done by others do not inadvertently get dropped. A related category mentioned by several of the SMEs was having a reminder to verify that tasks done by others were performed as intended, such as a consultant scheduling an appointment with the patient, a patient scheduling a critical appointment, or the appropriate person viewing the results of a biopsy to determine whether tissue sample indicates cancer. In one organization, an SME explained that specialist physicians have their performance measured by how many requested patients are seen within a time window such as six weeks. In situations where a patient needed to have a test done first or it was unlikely that the patient could be scheduled within that time, a relatively common practice was to cancel the original appointment request and ask the primary care physician to order another one in order to meet the performance expectation. This practice increased the risk that patients would fail to have care from a specialized physician within a desired time period. Some form of "tracking" functionality could be created to review a block of patients within a certain period of time who have had consults requested to determine if they had been scheduled. This functionality would display when a referral order was executed, when an appointment was made with the patient (or when a cancellation occurred), when a patient was notified of the appointment, when the patient attended the consultation session, when an evaluation was documented, when an evaluation was communicated, and when an evaluation was viewed by a primary care provider. Similarly, patients who have had labs or other procedures ordered which generate findings that are contained within the EHR could track whether they had been viewed since the findings had arrived.

In summary, the following opportunities to improve workflow were identified based on the discussions with several physician SMEs in ambulatory care:

- Scheduling support with at-a-glance overviews of patients for the day,
- Supporting remembering what to do during the patient visit,
- Cognitive warm-up support,
- Managing flow,
- Identifying time-critical notifications,
- Redacting and summarizing laboratory results,
- Drafting predicted orders,
- Transferring initiated tasks to another to complete,
- Supporting established diagnosis-based workflow,
- Supporting moving from working diagnoses to formal diagnoses,
- Supporting reviewing changes to medications,
- One-page patient summary,
- Supporting handing off patient education,
- Supporting dropping or delaying tasks under high workload conditions,
- Reducing time spent on documentation of provided care,
- Supporting different views of a progress note based upon role,
- Distinguishing new documentation from copied information,
- Supporting communication with specialist physicians about referrals and consultations,
- Supporting real-time documentation, and
- Tracking scheduled consults and review of laboratory results.

C. Managing conflicting goals: goal-means decomposition diagram

Many of the opportunities to improve workflow might conflict with goals, particularly for other nonclinical stakeholders. This is partly due to the historical situation in which coding and billing specialists tended to be the primary users of the first EHRs. In order to resolve usability and workflow issues raised primarily by physicians who have begun using EHRs, it is our belief that there may need to be a reprioritization of top-level goals for EHR use. Figure 8 displays a goal-means decomposition diagram, which is a human factors modeling method of displaying at lower levels in a visualization the means (how) for achieving higher-level goals.[lv] Generally there are two or three top-level goals which conflict, such as safety and production for a nuclear power plant which produces energy in a safe manner. Every level then is further deconstructed into the means for achieving the goal at a higher level. A goal-means decomposition is typically done in the context of a functional analysis for what functions will be viewed as useful by a particular group of users, mostly independently from the detailed mechanisms by which means are achieved. Note that there are many variations on visual representations of decompositions, as outlined in Table 1. This particular representation captures functions and the means for achieving them, and therefore is a ‘goal-means’ breakdown, as opposed to a hierarchical task analysis, which would depict tasks and subtasks in a ‘whole-part’ breakdown, similar to what would be done with a hierarchical organizational chart.

In Figure 8, for physicians in ambulatory care using EHRs to provide care to patients, we have identified three top-level goals: 1) patient care, 2) billing/reimbursement, and 3) physician quality

of work-life. From the physician's perspective, patient care is a higher priority than compensation or physician quality of work-life in general when there are goal conflicts which cannot be resolved in a way which fully meets all goals.

There is an interaction with the patient primarily with providing patient care and in the satisfaction for physicians from building and maintaining a positive relationship with the patient. Autonomy in clinical decision making, minimizing administrative burden, focusing on patient care and maintaining the quality of clinical care provider work-life are highly valued to clinicians. Workflows which adversely impact these values will result in, for example, a reduction in quality of work-life; and predictably will lead to increased clinician burnout, stress, and dissatisfaction with the work and with EHRs. Workflows that meet patient care needs and the needs of physicians to have a high quality of work-life might be viewed positively by end users and easily adopted, but may fail to meet the organization's needs for supporting billing and thus may be eventually replaced with a system that meets those needs. In particular, requirements to document compliance measures in order to avoid penalties need to be supported by the EHR functionality. This visualization highlights the need to identify stakeholders in the design of the workflow, and our recommendation is to prioritize primary clinical users over secondary administrative and billing users explicitly when there are trade-offs during design.

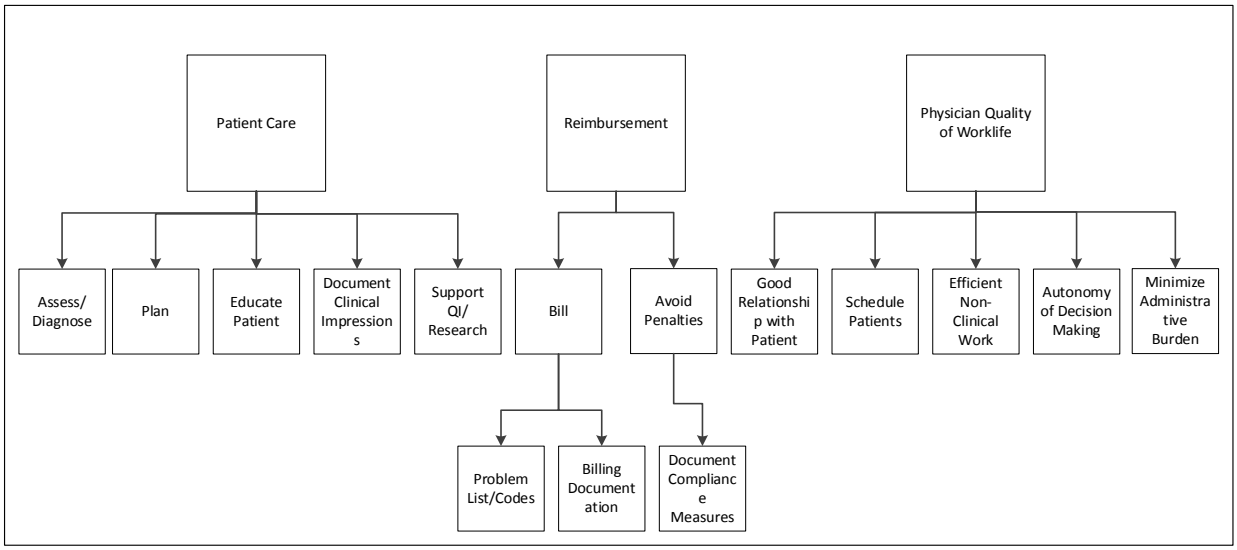

Figure 8. Goal-means decomposition diagram for EHR use by ambulatory physicians

4 Targeted Recommendations for EHR Developers and Ambulatory Care Centers for Improving Workflow

In order to make our insights easier to act upon, we have identified two groups which might benefit from what we have learned in this project: EHR developers and ambulatory care centers. Following are targeted recommendations which distill the lessons learned from the insights detailed in Section 3.

For EHR developers, we recommend the following to improve EHR-related workflow during the patient visit:

- Increase efficiency for these tasks:
    - Reviewing results with the patient,
    - Drafting pre-populated orders to be formally executed later, and
    - Supporting drafting documentation with shorthand notations without a keyboard;
- Design for empathetic body positioning and eye contact with the patient while personally interacting with the EHR and while sharing information on the EHR screen with the patient and family members;
- Support dropping tasks and delaying completion of tasks to help with daily flow; and
- Verification of alarms and alerts and data entry without "hard stops."

For ambulatory care centers, we recommend the following to improve EHR-related workflow during the patient visit:

- Moderate organizational design flexibility (staffing, processes);
- Design room to support patient rapport and EHR access;
- Minimize redundant data entry from interoperability;
- Reduce clinic pace or increase flexibility of pace;
- Ensure functionality that supports continuity in the task performance in the case of interruption (which will allow one person starting and another completing tasks); and
- Relax requirements to enter detailed data for others (administrators, billing/coding, legal, accreditation) during fast-paced patient visits.

Overall, our recommendations provide a first step in moving from a billing-centered perspective on how to maintain accurate, comprehensive, and up-to-date information about a group of patients to a patient -centered perspective. This perspective more centrally revolves around the needs of primary care providers, including physicians, physician assistants, and nurse practitioners. These recommendations point the way towards a "patient visit management system," which incorporates broader notions of supporting workload management, supporting

flexible flow of patients and tasks, enabling accountable distributed work across members of the clinical team, and supporting dynamic tracking of steps in tasks that have longer time distributions. For example, the concept of “ordering a medication” involves concepts of anticipating potential orders, updating order expectations with input from patients regarding their priorities and new information, revising the details of orders in order to meet reimbursement and other requirements, and tracking the status of tasks done by others prior to a patient receiving the medication.

As electronic health records are conceptualized in order to better fit the workflow patterns in physician offices, the insights from our SMEs in several cases identified affordances which were available in a paper-based system but were not easily translated into the current generation of electronic health records. Their comments are not provided in order to suggest a return to paper, but rather to identify functionality to support with the electronic health record design as well as with choices made during the implementation of electronic health records. There are several ways in which paper-based documentation was more flexible in nature. One is that access to a piece of paper for entering, viewing, highlighting, updating, and annotating information was done by other means (primarily physical constraints) than by an electronic login with an associated defined organizational role. Another is that it was rather difficult to update and disseminate changes to paper forms, particularly to add requirements for additional documentation, but that this is much easier to do in an electronic environment. In particular, it is easier for administrative or other personnel to embed required documentation elements, create templates with required items to complete within a workflow, or enforce a structure upon entered information with an electronic format. Getting a "gist" of how complicated a patient or collection of patients are was possible naturally with paperwork that had more pages when it was longer as compared to electronic icons without this information and which are only available when requested to be viewed. Changing the sequencing of patients with paper was more naturally done than with electronic health records. Finally, workflow variations tend to be easier to accommodate with patients.

Real-time adjustments by staff to variation in workflow is clearly important to provide a high quality of care, have efficient patient flow, meet reimbursement objectives, and allow a reasonable quality of work-life for staff. These are not just mechanical sequences of pre-identified tasks, but are contextual and have high variability across patients, providers, units, and organizations. There are variations in workflow at multiple levels, and workflow for individual patients combine to create a series of activities for a physician to complete. Workflow for physicians is integrated with the workflow of supporting members of a team. The workflow of the team is coordinated with consultations with specialists with clinical expertise. The workflow of the clinical personnel is integrated with the workflow of billing and legal personnel. Elements of documentation produced from the workflow can be analyzed for patterns that can be used for quality improvement and research purposes. In an electronic environment, new capabilities are available to allow new forms of interaction and communication, which subsequently changes the nature of the work itself, and thus the routine and exceptional workflows that need to be supported.

5 Conclusion

In response to workflow integration challenges with ambulatory physicians using EHRs, we have employed standard human factors methods in order to identify insights for EHR developers and ambulatory care centers. The methods illustrated in this document are process maps and goal-means decomposition diagrams informed by goal-oriented individual collegial discussions with physician Subject Matter Experts to walk through the typical workflow of a returning patient in an ambulatory care setting. We have identified a wide variety of potential opportunities to improve workflow with EHRs from a physician perspective. We anticipate that improving workflow might require an expansion in focus from the historical goal of supporting reimbursement to also improving quality of patient care as well as the quality of work-life for physicians. In order to increase the ease of implementing our insights, we provide a set of targeted recommendations.

6 References

[1]Jha, A.K., Desroches, C.M., Campbell, E.G., et al. "Use of electronic health records in U.S. hospitals." *The New England Journal of Medicine,* 2009;360(16):1628–1638.

[2]Bates, D.W., Gawande, A.A. "Improving safety with information technology." *The New England Journal of Medicine*, 2003;348:2526-2534.

[3]Bates, D.W. "Using information technology to reduce rates of medication errors in hospitals." *BMJ,* 2000;320:788-791.

[4]Bates, D.W. "Using information technology to screen for adverse drug events." *Am J Health Syst Pharm,* 2002;59:2317-2319.

[5]Bates, D.W. "The quality case for information technology in healthcare." *BMC Med Inform Decis Mak,* 2002;2:7.

[6]Boukhors ,Y., Rabasa-Lhoret, R., Langelier, H., Soultan, M., Lacroix, A., Chiasson, J.L. "The use of information technology for the management of intensive insulin therapy in type 1 diabetes mellitus." *Diabetes Metab,* 2003;29:619-627.

[7]Gawande, A.A., Bates, D.W. "The use of information technology in improving medical performance. Part I. Information systems for medical transactions." *MedGenMed,* 2000;2:E14.

[8]Kaushal, R., Bates, D.W. "Information technology and medication safety: what is the benefit?" *QualSaf Health Care,* 2002;11:261-265.

[9]Nold, E.G. "Trends in health information systems technology." *Am J Health Syst Pharm,* 1997;54:269-274.

[10]Sahm, D.F., Thornsberry, C., Karlowsky, J.A. "The application of information technology to regional, national, and global surveillance of antimicrobial resistance." *Curr Pharm Des,* 2003;9:969-974.

[11] Skinner, R.I. "The value of information technology in healthcare." *Front Health Serv Manage,* 2003;19:3-15.

[12] Stead, W.W., Sittig, D.F. "Building a data foundation for tomorrow's healthcare information management systems." *Int J Biomed Comput,* 1995;39:127-131.

[13] Middleton, B., Bloomrosen, M., Dente, M.A., et al. "Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA." *Journal of the American Medical Informatics Association,* 2013.

[14]Lee, J., Cain, C., Young, S., Chockley, N., Burstin, H. "The Adoption Gap: Health Information Technology in Small Physician Practices." *Health Aff.* 2005 September; Vol. 24 No. 5 1364-1366.

[15]Nakamura, M.M., Ferris, T.G., DesRoches, C.M., Jha, A.K. "Electronic health record adoption by children's hospitals in the United States." *Arch Pediatr Adolesc Med.* 2010 Dec;164(12):1145-51.

[16] Chiang, M.F., Read-Brown, S., Tu, D.C., Choi, D., Sanders, D.S., Hwang, T.S., Bailey, S., Karr, D.J., Cottle, E., Morrison, J.C., Wilson, D.J., Yackel, T.R. "Evaluation of electronic health record implementation in ophthalmology at an academic medical center (an American Ophthalmological Society thesis)." *Trans Am Ophthalmol Soc.*, 2013 Sep;111:70-92.

[17]"IDC Health Insights. Business Strategy: The Current State of Ambulatory EHR Buyer Satisfaction," *IDC Health Insights (Doc #HI244027)*, November 2013.

[18] Lowry, S. Z., Quinn, M. T., Ramaiah, M., Brick, D., Patterson, E. S., Zhang, J., Gibbons, M. C., Abbott, P. "A Human Factors Guide to Enhance EHR Usability of Critical User Interactions

when Supporting Pediatric Patient Care." *NIST Interagency/Internal Report (NISTIR) – 7865*, 2012. Available at: http://www.nist.gov/healthcare/usability/upload/NIST-IR-7865.pdf.

[19] Zhang, J., Walji, M. "TURF: Toward a unified framework of EHR usability." *Journal of Biomedical Informatics*, 44(6): (2011) 1056-1067.

[20]"Ergonomic requirements for office work with visual display terminals (VDT)s - Part 14 Menu dialogues," *ISO/IEC 9241-14: 1998 (E)*, 1998.

[21]Flach, J.M., Dominguez, C.O. "Use-centered design: Integrating the user, instrument, and goal." *Ergonomics in Design: The Quarterly of Human Factors Applications*, July 1995 vol. 3 no. 3 19-24.

[22] Svetlana, L.Z., Matthew, Q.T., Ramaiah, M., Schumacher, R.M., Patterson, E.S., North, R., Zhang, J., Gibbons, M.C., Abbott, P. "NISTIR 7804 Technical Evaluation, Testing and Validation of the Usability of Electronic Health Records." *NIST Interagency/Internal Report (NISTIR) – 7804*, 2012. Available at: http://www.nist.gov/customcf/get_pdf.cfm?pub_id=909701.

[23]Carayon, P., Karsh, B.T., Cartmill, R. "Incorporating Health Information Technology into Workflow Redesign-Summary Report." *AHRQ Publication No. 10-0098-EF*, 2010.

[24]Carayon, P., Karsh, B.T., Cartmill, R. "Incorporating Health Information Technology into Workflow Redesign-Summary Report."*AHRQ Publication No. 10-0098-EF*, 2010.

[25]Middleton, B., Bloomrosen, M., Dente, M.A., et al. "Enhancing patient safety and quality of care by improving the usability of electronic health record systems: recommendations from AMIA." *Journal of the American Medical Informatics Association*, 2013.

[26] Friedberg, M.W., Chen, P.G., Van Busum, K.R., Aunon, F.M., Pham, C., Caloyeras, J.P., Mattke, S., Pitchforth, E., Quigley, D.D., Brook, R.H., Crosson, J.F.J., and Tutty, M. "Factors Affecting Physician Professional Satisfaction and Their Implications for Patient Care, Health Systems, and Health Policy." *Santa Monica, Calif.: RAND Corporation*, RR-439-AMA, 2013.

[27] Friedberg, M.W., Van Busum, K., Wexler, R., Bowen, M., Schneider, E.C. "A demonstration of shared decision making in primary care highlights barriers to adoption and potential remedies," *Health Affairs*, 32(2):268-275, 2013.

[28]Thielke, S., Hammond, K., Helbig, S. "Copying and pasting of examinations within the electronic medical record." *International Journal of Medical Informatics*, Volume 76, Supplement 1, Pages S122-S128, June 2007.

[29] Patterson, E.S., Cook, R.I., Render, M.I. "Improving patient safety by identifying the side effects of introducing bar coding to medication administration." *Journal of American Informatics Association*, 200;9 :540-53.

[30] Harrington, Linda, Kennerly, D.and Johnson, Constance. "Safety issues related to the electronic medical record (EMR): synthesis of the literature from the last decade, 2000-2009." *Journal of healthcare management/American College of Healthcare Executives* 56.1 (2010): 31-43.

[31]Koppel, R., Kreda, D.A. "Healthcare IT usability and suitability for clinical needs: challenges of design, workflow, and contractual relations." *Studies in Health Technology and Informatics.* 2010, 157:7-14.

[32]Cain, C., Haque, S. "Organizational Workflow and Its Impact on Work Quality. In: Hughes RG, editor. Patient Safety and Quality: An Evidence-Based Handbook for Nurses." Rockville (MD): Agency for Healthcare Research and Quality (US); 2008 Apr. Chapter 31.

[33]Definition approved by the council of the IEA in 2000. http://www.iea.cc/01_what/What%20is%20Ergonomics.html. Accessed November 18, 2013.

[34] Xiao, Y., Fairbanks, R.J., Gurses, A.P., Nemeth, C., Roth, E., Wears, R.L., Gorman, P. "User Created Cognitive Artifacts: What Can They Teach Us About Design of Information Technology?." *Proceedings of the Human Factors and Ergonomics Society 53rd Annual Meeting*, 2009. pp. 694-698.

[35]Wharton, C., et al. "The cognitive walkthrough method: a practitioner's guide." *J. Nielsen & R. Mack "Usability Inspection Methods"* pp. 105-140.

[36]Beyer, H., Holtzblatt, K. “Apprenticing with the Customer.” *Communications of the ACM*, May 1995.
[37] Sanderson, Penelope, et al. "Use of cognitive work analysis across the system life cycle: From requirements to decommissioning." *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. Vol. 43. No. 3. SAGE Publications, 1999.
[38]Waldemar, K., MarcioSoares, M., Neville ,A., Stanton, eds. *Human Factors and Ergonomics in Consumer Product Design: Uses and Applications*. Vol. 2.CRC Press, 2011.
[39] Human Factors Engineering of Software User Interfaces (HFES 200). Human Factors and Ergonomics Society Publication, 2008.
http://www.hfes.org//Publications/ProductDetail.aspx?ProductId=76 .
[40]Woods, David, and Dekker, Sidney. "Anticipating the effects of technological change: a new era of dynamics for human factors." *Theoretical Issues in Ergonomics Science* 1.3 (2000): 272-282.
[41]Mahatody, Thomas / Sagar, Mouldi / Kolski, Christophe (2010). State of the Art on the Cognitive Walkthrough Method, Its Variants and Evolutions, International Journal of Human-Computer Interaction, 2, 8 741-785.
[42]Endsley, M. R. (1995). Measurement of situation awareness in dynamic systems. Human Factors, 37 (1), 65-84
[43]Rasmussen, J. Information Processing and Human-Machine Interaction, North-Holland, New York, 1986.
[44]Annett, J. (2003). Hierarchical Task Analysis. In E. Hollnagel (Ed.), *Handbook of Cognitive Task Design* (pp. 17 - 35). Mahwah, NJ: Lawrence Erlbaum Associates.
[45]Bødker, K., Kensing, F., Simonsen, J. “Participatory IT design: Designing for business and workplace realities.” *Cambridge, MA, USA: MIT Press*, 2004.
[46]Sanders, Ross and Coleman 'The Process Map', *Quality Engineering*, 11(4) July 1999, 555 - 561.
[47]Virzi, Robert A., Jeffrey L. Sokolov, and Demetrios Karis."Usability problem identification using both low-and high-fidelity prototypes."*Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*.ACM, 1996.
[48]Sharp, Helen, Anthony Finkelstein, and GalalGalal."Stakeholder identification in the requirements engineering process." *Database and Expert Systems Applications, 1999. Proceedings.Tenth International Workshop IEEE*, 1999.
[49]Bisantz, A. and Roth, E. M. (2008). Analysis of Cognitive Work. In Deborah A. Boehm-Davis (Ed.) *Reviews of Human Factors and Ergonomics Volume 3*. Santa Monica, CA: Human Factors and Ergonomics Society. 1-43.
[50]Crandall, B., Klein, G. A., & Hoffman, R. R. (2006). *Working Minds: A Practitioner's Guide to Cognitive Task Analysis*. Cambridge, MA: The MIT Press.
[51]Saleem, J. J., et al. "Impact of clinical reminder redesign on learnability, efficiency, usability, and workload for ambulatory clinic nurses." *Journal of the American Medical Informatics Association* 14.5 (2007): 632-640.
[lii]Murphy, D.R., Reis, B., Kadiyala, H., et al. Electronic Health Record–Based Messages to Primary Care Providers: Valuable Information or Just Noise? *Arch Intern Med.* 2012;172(3):283-285.
[liii]Sorace J., Wong, H.H., Worrall, C., Kelman J., Saneinejad S., MaCurdy T. “The complexity of disease combinations in the Medicare population.” *Popul Health Manag.* 2011 Aug;14(4):161-6.
[liv]Zhou, X., Zheng, K., Ackerman, M.S., Hanauer, D. Cooperative Documentation:
The Patient Problem List as a Nexus in Electronic Health Records. Proceedings of CSCW 12; 2012: 911-920.
[lv]Rasmussen, J. Information Processing and Human-Machine Interaction, North-Holland, New York, 1986.