NISTIR 8042

Integrating Electronic Health Records into Clinical Workflow: An Application of Human Factors Modeling Methods to *Obstetrics and Gynecology* and *Ophthalmology*

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This publication is available free of charge from:
http://dx.doi.org/10.6028/NIST.IR.8042

National Institute of Standards and Technology
U.S. Department of Commerce

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February 2015

U.S. Department of Commerce
Penny Pritzker, Secretary

National Institute of Standards and Technology
Willie May, Acting Under Secretary of Commerce for Standards and Technology and Acting Director

Acknowledgments

The authors gratefully acknowledge the intellectual contributions from the following reviewers:

- Catalin Buhimschi, MD, Professor, Department of Obstetrics & Gynecology, Ohio State University
- Michael L. Hodgkins, MD, MPH, Chief Medical Information Officer, American Medical Association
- Madhavi Kurli, MD, Advanced Retina and Eye Cancer Center
- Ramu Muniraju, MD, MRCO, MSc, Consultant Ophthalmic Surgeon with special interest in Medical Retina, Ashford and St. Peter's Hospitals, NHS Foundation Trust and Clinical Lead Surrey National Diabetic Eye Screening Programme
- A. Gwendolyn Noble, MD, PhD, Department of Ophthalmology, Ann and Robert H. Lurie Children's Hospital of Chicago, Northwestern University and Department of Ophthalmology and Visual Sciences, The University of Chicago
- Jess A. Pawlak, MS PMP CISA CHPS, Lumetra Healthcare Solutions
- Jayashree Ramu, MBBS, Clinical Research Fellow, Moorsfield Eye Hospital, NHS Foundation Trust
- Kara Rood, MD, Maternal Fetal Medicine Fellow, Obstetrics and Gynecology, Wexner Medical Center, The Ohio State University
- Bennett Spetalnick, MD, Obstetrics and Gynecology, Vanderbilt University
- Alex Vu, BS, Systems Developer for Clinical Applications, College of Optometry, Ohio State University Medical Center
- Dan Yin, MD, Ophthalmologist, Washington Eye Consultants

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Table of Contents

Executive Summary

Adoption of Electronic Health Record (EHR) systems in all care settings 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 specialty care settings. 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 this report, a human factors workflow modeling tool, process mapping, was used to visualize and document insights and the end-user needs to improve EHR workflow for clinicians in two specialty outpatient care settings: 1) Obstetrics and Gynecology (Ob-Gyn) and 2) Ophthalmology. The findings identified clinical activities that required better coordination with specialized technicians (Ob-Gyn assistants and Ophthalmology technicians), better integration with specialized software and devices (fetal strips and a software for Ob-Gyn and OCT machines for Ophthalmology), unique data fields (number of drops and which eye in Ophthalmology), and 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 two interdisciplinary team meetings with clinical and human factors experts, we created process map visualizations and identified opportunities for innovation.

The insights identified a wide range of opportunities to improve workflow through enhanced functionality with the EHR for both specialty care areas. Although the specific examples and relative importance for the opportunities differed for the two specialties, there was remarkable similarity in the opportunities which were identified. The opportunities that were both found for both specialties' EHR functionality included:

- Before the patient visit, supporting:
    - Reducing the risk of missing a target window of opportunity to provide optimal care actions due to scheduling issues
    - Distinguishing between patients with a very high likelihood of getting a particular treatment from patients who are less likely to get the treatment
    - Alerting physicians to information about patients that informs how to conduct a patient visit
    - Integrating medication information from pharmacies, hospitals and current insurance formularies into the EHR
    - Verifying that insurance requirements are met during the scheduling process
    - Flexible real-time assignments of different staff to tasks across multiple patients simultaneously
    - Usable access to patient data from diverse hardware platforms, including mobile devices
- During the patient visit, supporting:
    - Displaying summary information in a format which matches how specialist physicians were trained to recognize patterns
    - Reminding the physician of planned tasks to accomplish during a patient visit
    - Integration of personal health record data, patient portal information, and patient entered information
    - Cosigning of ancillary support notes and findings
    - Integration of previously entered patient data into the current visit
    - Multiple simultaneous patient evaluations
    - Hands-free interaction with the EHR during procedures

    - Integrating information from specialized devices, software, data repositories
    - Grouping conceptually related items with different formats (e.g., CIF, image, scanned image, fax, PDF, searchable text, structured data), particularly redundant data
    - Locating original images on image acquisition devices when viewing electronically stored images
    - Viewing annotations about data quality at the top level screen view
    - Graphing of viewing formatted data (tables) over time to identify patterns and trends, including extracting data from devices and standardized files
    - Providing a draft order set to modify during the visit which is tailored to diagnostic and demographic information
    - Verifying that recently changed insurance and regulatory requirements are met when ordering and interpreting diagnostic tests
    - Providing quick access to short summary syntheses of findings from recent research
    - Selecting correct administrative diagnostic and procedural codes (ICD, CPT) for the visit documentation
    - Selecting patient's current insurance plan's pharmaceutical formulary
    - Providing medical necessity documentation for procedures, medications, transportation, convalescence, or work restriction
    - Meeting informed consent requirements with procedure specific details
    - A holistic approach to the goal of optimizing patient compliance to scheduled follow-ups and needed medical regimen
    - Integrating surgical notes into the EHR
    - Identifying, retrieving and displaying prior similar specialty prior notes
    - Comparing images over time within the EHR
    - Having orders include unique data fields for the specialty area
    - Drawing templates with annotations, icons, and auto-generated text
    - Sub-specialty-specific classification of patients based upon examination findings
- At the conclusion of the visit, supporting:
    - Informing patients about whether medications need to be obtained immediately following the visit
    - Informing patients about what to watch for and who to contact if particular events happen
    - Optional redaction of particularly sensitive patient information from after-visit summaries
    - Optimizing patient compliance
- For documentation, supporting:
    - Correcting auto-generated information which is inaccurate
    - Viewing of all information that will be saved in the EHR before being saved
    - Draft documentation and encounter forms which are tailored to diagnostic information
    - Reducing log-ins and sign-offs for multiple software packages and devices used to accomplish related functions
    - Annotating documentation by patients and caregivers in a progress note
    - Advanced features for image management, including extraction of quantitative data and images without being dependent on interfaces with other applications
    - Having additional protections on personal health information

Targeted recommendations for EHR developers and Ob-Gyn and Ophthalmology centers to improve workflow integration with EHRs are proposed to improve quality of care, improve patient safety, and reduce medical-legal exposure.

These recommendations provide a first step in understanding what the unique needs of two diverse specialty care areas are in order to better support workflow in general outpatient care settings. Some of

the recommendations relate directly to improving patient safety, including ensuring that patients receive treatments within evidence-based time intervals, providing integrated access to data from specialized devices in an efficient and usable manner, having orders include unique data fields for the specialty area such as drops in the right or left eye, and having visual representations of data match specialty-specific norms, such as having the right eye be defined from the perspective of the patient. Recommendations include better support for non-clinical aspects of workflow for these specialties, such as scheduling patients for treatments at recommended time intervals and documentation of specialty-specific information, in order to facilitate high quality provider-patient interaction during a visit.

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] Barriers to adoption of health information exchange in small to medium sized family medicine practices include workflow.[17] A facilitator to adoption of health information exchange in a recent study in primary care settings was found to be use-by-proxy strategies whereby medical scribes, clerks, case managers, and assistants retrieve data and relay the information to the physician during the point of care.[18] 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.[19] Similarly, a recent mixed-methods study found that poor EHR usability, time-consuming data entry, and degradation of clinician documentation were among the prominent sources of professional dissatisfaction for physicians.[20]

The purpose of this report is to demonstrate how applying human factors modeling methods can improve EHR workflow integration into the clinical workflow for specialty care areas. 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 who provide care in two different specialty areas 1) Obstetrics and Gynecology and 2) Ophthalmology. Obstetrics and Gynecology is a diversified specialty concerned with the delivery of medical and surgical care to women. Per the Association of American Medical Colleges, this field combines two specialties: Obstetrics, which focuses on the care of women before, during, and after childbirth; and Gynecology, which involves the diagnosis and treatment of disorders of the female reproductive system, breasts, and associated disorders. Ophthalmology deals with the structure, function, diagnosis, and treatment of the eye and the visual system. Similarly, per the Association of American Medical Colleges, this includes problems affecting the eye and its component structures, the eyelids, the orbit, and the visual pathwaysIn this report, we will first consider challenges with the workflow for a returning patient in an outpatient clninic in Obstetrics and Gynecology, second in Ophthalmology, and finally make targeted recommendations to improve workflow in both specialties.

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.[21] 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."[22]

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."[23] 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.[24] 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.[25] 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"[26] concluded that workflow analysis was needed in order to ensure successful health IT implementation.

Workflow has emerged as an issue for EHR adoption, productivity,[27] and professional satisfaction for physicians.[28] 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.[29] 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. Benefits of copying and pasting a previous note include efficiency and prompting for the review of updates to previous findings. Suboptimal impacts of copying and pasting can include perpetuating inaccurate or outdated information or failing to take out documentation of activities which were not done during the visit resulting in inaccurate billing, as well as the potential of pasting information into the wrong patient's chart when multiple charts are open at one time. In one study, 25% of patient charts had text copied from prior clinical examinations, which if pasted without needed corrections can lead to confusion, medical error, and medico-legal harm.[30]

It is important to understand the potential impact of workarounds on patient safety. Designing systems that are poorly integrated into workflow may make it difficult for clinicians to be aware of critically important information when making diagnoses and creating treatment plans, thus leading to suboptimal care or delayed care. In addition, design that is not optimized for a specialty care area's workflow may inadvertently 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.[31] In addition, EHR documentation may not allow for the variety 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.[32] 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[33] 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.

This report focuses on two specialty care area ambulatory (outpatient) care settings. In both specialty care settings, there can be support staff for the physician with specialized knowledge and expertise beyond what is typical for non-specialty care settings. In Obstetrics and Gynecology care, an Ob-Gyn assistant obtains vital signs, collects urine and blood samples, prepares equipment, preps the patient, operates ultrasound machines, and relays medical information and instructions to patients. In Ophthalmology, Ophthalmic technicians work under the supervision of an Ophthalmologist to do clinical tasks such as measuring visual acuity, instilling ocular medications, obtaining historical information, and instructing the patient regarding medications, tests, and procedures. In all ambulatory care settings, there can be a range of staff. For example, there can be 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 annual gynecologic visit in a clinic and the associated workflow is very different from the continuous monitoring and documentation in a clinic when a pregnant patient with unstable blood pressure readings has recently experienced significant trauma.

2 Application of Human Factors Workflow Modeling Tool

Process mapping was selected to demonstrate that the application of human factors workflow modeling tools can improve EHR workflow integration into the clinical workflow for specialty care areas, even without considering workflow concerns related to implementation at a particular organization. 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. In a prior report, NISTIR 7988 "Integrating Electronic Health Records into Clinical Workflow: An Application of Human Factors Modeling Methods to Ambulatory Care"[34], we provided a literature review of a wide range of potential human factors workflow modeling tools and guidance on how to select an appropriate tool to meet project objectives.

This approach was purposefully selected in order to illustrate a human factors approach 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 outpatient 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 the physicians with experience in the two specialty 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 the two areas of specialty care, and had a diverse perspective on the ideal level of integration of EHRs into routine and exceptional workflows. In Obstetrics and Gynecology, there were four physicians, including a senior physician with administrative experience, two senior physicians with informatics expertise, and a fellow physician who specialized in high-risk Obstetrics care. In Ophthalmology, there were two ophthalmologists, one of whom subspecialized in uveitis. 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. In one instance, a correction was provided following the discussion regarding the level of integration of fetal heart rate monitor data with the electronic health record. For both specialty care areas, we additionally verified the accuracy of the information with informatics specialists who supported the specialty care areas during a one-hour one-on-one discussion with the human factors expert. 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 that were supported were further refined.

The process model was iteratively generated and revised over a series of meetings for Ophthalmology with a physician and from notes from discussions with four physicians in Obstetrics and Gynecology. The representations were constructed with a commercial flowchart program. The maps are 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, it is anticipated that workflow will vary based on whether the physician is ahead of or behind the day's schedule. Nevertheless, the process maps used in this project are a useful representation in that they identify prerequisites for certain steps, distinguish steps which are required for regulatory/certification purposes from other activities, and identify 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.

For both specialties, we have organized insights from our discussions with SMEs into five categories: 1) before the patient visit, 2) during the patient visit, 3) during the physician encounter, 4) discharge, and 5) documentation. We have chosen to focus on a physician interacting with an EHR with support by a technical specialist, but without support by a physician extender, case manager, or scribe. 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 for their specialties which they order, particularly if dosages are changing or they are high-risk, have correct dosages.

3 Process Maps and Workflow Redesign Opportunities for Ob-Gyn

Steps in the workflow are visualized in Figure 1 as an overview at a high level of the details in Ob-Gyn for EHR interactions related to an established patient's return visit with the specialist care provider in an outpatient setting. These steps are grouped as follows:

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

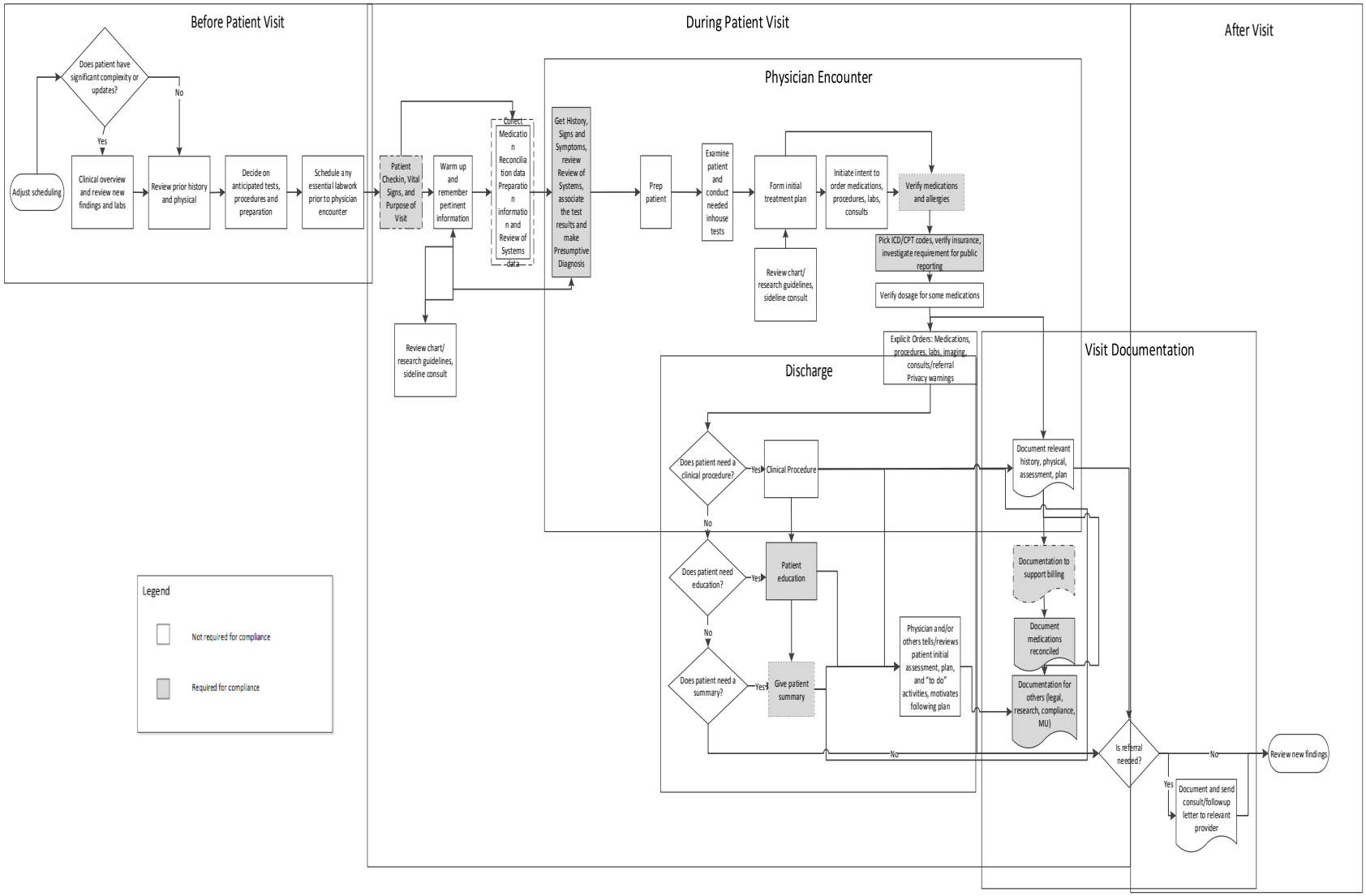

Figure 1. Overview process map for EHR use related to returning patient visit in Ob-Gyn
(*Tip:* Printing this page on a paper of size A3 or larger provides legibility to read the contents)

3.A. Before the patient visit

In Figure 2, there is an example of the process steps related to activities occurring with the EHR before the visit in Ob-Gyn. These are:

- Adjust scheduling in order to balance workload demands and take into account predictions and updates about how long types of patients will take and to meet the unexpected urgent needs of scheduled and unscheduled patients,
- Clinical overview and review new findings and labs for patients with significant complexity and updates,
- Review prior history and physical for all patients,
- Decide on anticipated tests, procedures, and preparation,
- Map the patient's schedule with the technician's schedule to decide what is possible and not possible to do at the visit.

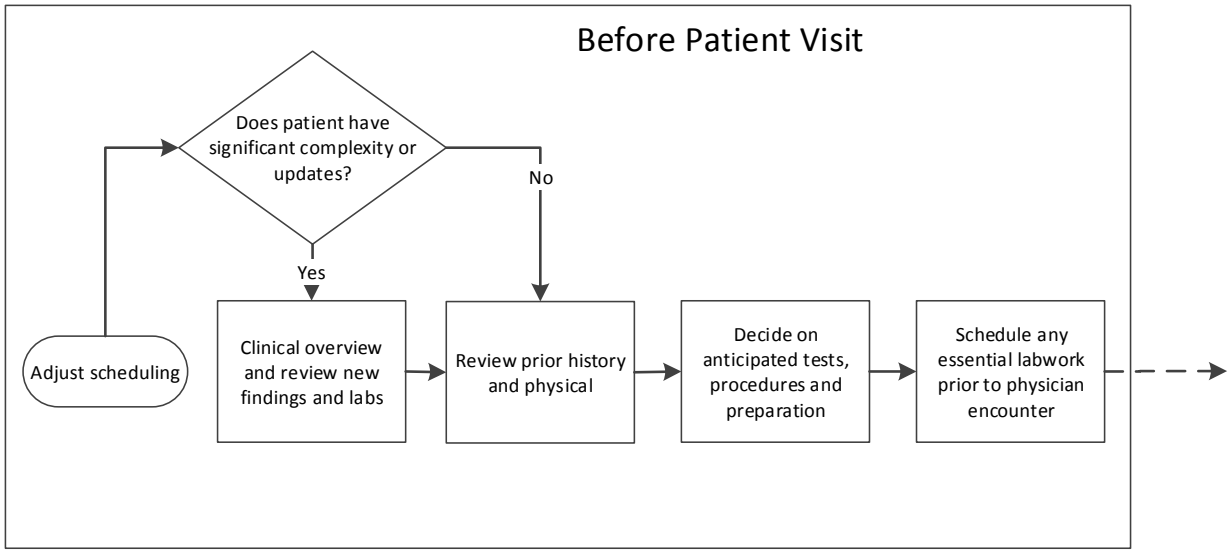

Figure 2. Process map for activities conducted before a returning patient visit with the EHR in Ob-Gyn

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Many of these were decision support enhancements based upon information about the specific patient which would be available in the EHR. Opportunities for providing support during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

3.A.1. Reducing the risk of missing a target time interval to provide optimal care actions due to scheduling issues

In Ob-Gyn, there are time intervals to provide optimal care which are considered when adjusting scheduling. When patients are scheduled outside of that window, the care is less than optimal, and in some cases, there are patient safety concerns that arise. In obstetrics, visits and treatments are scheduled based upon the age of the fetus. For example, the first ultrasound imaging scan is performed before the end of the first trimester (i.e., less than 13 weeks). Having the scan before this time is important for accurately determining gestational age, which impacts the ability to accurately conduct serum screening for Down's syndrome. Visualizations which highlight appointments that are past the recommended window or alerts about patients who have not yet been scheduled in the recommended timeframe for a recommended care action could reduce the risk of missing the target time interval. Similarly, patients who

have reached stability can have increased flexibility in scheduling, including being deferred to longer intervals if a patient with more urgent needs has to be accommodated during scheduling.

3.A.2. Distinguishing between patients with a very high likelihood of getting a particular treatment from patients who are less likely to get the treatment

In Ob-Gyn, there are predictable patterns of care which can form the basis for visit checklists, order sets, encounter forms, and other documentation facilitation. In addition, there are indicators that could be taken advantage of relating to the certainty that plans will go as expected. In Gynecological care, the annual visit is likely to follow a predictable routine unless there are chronic problems such as hypertension, or diabetes, or past abnormal findings from PAP smears or endometrial biopsies. For patients with diagnoses specific to Ob-Gyn care, there are predicted treatment actions that are taken with a high certainty. Nevertheless, there are known exceptions to how these treatments are conducted, and alerting physicians in a prominent fashion to these factors would be highly useful. For example, in Obstetrics care, a patient may have had a lab result indicating protein in the urine on the last visit. When there is a "best practice" standard for care with consensus across providers, then templates could be built to support efficient use of standardized protocols.

3.A.3. Alerting physicians to information about patients that inform how to conduct a patient visit

In Ob-Gyn care, providers employed techniques to provide alerts when opening a patient's chart that were helpful to tailoring the conduct of a patient visit. In most cases, these techniques were "positive workarounds" in that they used EHR functionality which was not designed for that purpose, and thus the use was less than optimal, if only because the other intended use was affected. Examples include using the problem list to identify patients who have already had the Tetanus-Diphtheria (TDAP) vaccination in a prior pregnancy or who lack the Rh antigen (e.g., is Rh-negative). Having this information incorporated into a tailored specialty care overview display would eliminate the need to have additional pop-up alerts or problem list items.

3.A.4. Integrating medication information from pharmacies, hospitals and insurance formularies into the EHR

Obtaining accurate information about what medications a patient has been taking can be a challenging process for many reasons. Although there can be reasons for why the information might be incomplete or inaccurate, one of the more trusted sources of information is the pharmacy where a patient obtains the medication and the hospital where medications were administered during an inpatient stay. Insurance formularies and prescription drug benefits are important sources of information because this has the preferred list for what the patient has available and must pay to receive medications. Having this information integrated directly into the EHR would be beneficial when eliciting and verifying information about medications from patients and caregivers for both clinical and reimbursement purposes.

3.A.5. Verifying that insurance requirements are met during the scheduling process

In Ob-Gyn, some elements of the treatment plan can be determined based upon insurance requirements. When procedures or medications cost thousands of dollars, it is important to verify that insurance requirements are met during the scheduling process. Providing EHR functionality to ensure that these requirements are met during the scheduling process would be useful in order to allow the specialist physicians to focus more on the clinical aspects of the visit. In Gynecological care, some insurance companies have exclusions for coverage for birth control methods. For example, there is a non-surgical birth control outpatient procedure which costs thousands of dollars to perform.

3.A.6. Flexible real-time assignments of different staff to tasks across multiple patients simultaneously

There can be a high variability in terms of whether ancillary staff or specialist physicians do certain tasks, The flow of the day is improved when the assignment of tasks is flexible based upon bottlenecks that

emerge during the day. Having the ability to flexibly allocate and re-allocate assignments would be useful. Flexible allocation requires that the personnel assigned to meet requirements for reimbursement, accreditation, and for other entities are supported in the sequence of events (ordering in the chart can be required to be conducted before the procedure), documentation of interpretations in the correct portion of the chart by the appropriate person, and required sign-offs by primary care providers. Examples where specialized support staff can be assigned tasks include an ultrasound imaging (sonography) technique of the fetus.

3.A.7. Usable access to patient data from diverse hardware platforms, including mobile devices

Specialty care providers may work in a variety of clinical settings, even within a single day when time spent going from one setting to another can be used to prepare for patient visits. In different settings, there might be different platforms which are required to be used by the relevant organizations. In addition, requests for care may come outside of scheduled clinic hours, when mobile devices need to be used to respond to care requests. Therefore, usability of software needs to be achieved from diverse hardware platforms, including mobile devices and other platforms with limited screen size and no keyboard or touch screen interactions. Allowing efficient access from mobile devices would require meeting requirements for information security and information governance without excessive additional logins or other keyboard or screen interactions.

3.B. During the patient visit

In Figure 3, the process steps related to activities occurring with the EHR during the returning patient visit in obstetrics care for a pregnant patient are shown. In obstetrics care, the pregnant patient is the "prototypical" case. Patients can also come for miscarriages, etc., but pregnancy is the most common example. The workflow varies for more complex patients. 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 during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

3.B.1. Displaying summary information in a format which matches how specialist physicians were trained to recognize patterns

In Ob-Gyn, specialist physicians had standardized specialized formats for viewing data within their fields. Detecting patterns and trends using these formats is central to diagnosis and treatment. For example, in prenatal care, the antepartum record has been standardized by the American Congress of Obstetricians and Gynecologists (ACOG), and has recommended that vendors reproduce this in electronic format.[35] At this time, no vendor has yet been known to have done this formally, although some have the ability for providers to generate templates which could incorporate most of this information in a similar fashion as has been recommended. This format promotes the ability to see if a finding is new, such as protein in the urine, if there has been an unexpected change in fundal height, whether blood pressure is trending upward, etc. With the paper version, there was a standardized sense of "left and right" side of the chart and where to look for information and no need to "scroll" or otherwise manipulate the interface to quickly skim information.

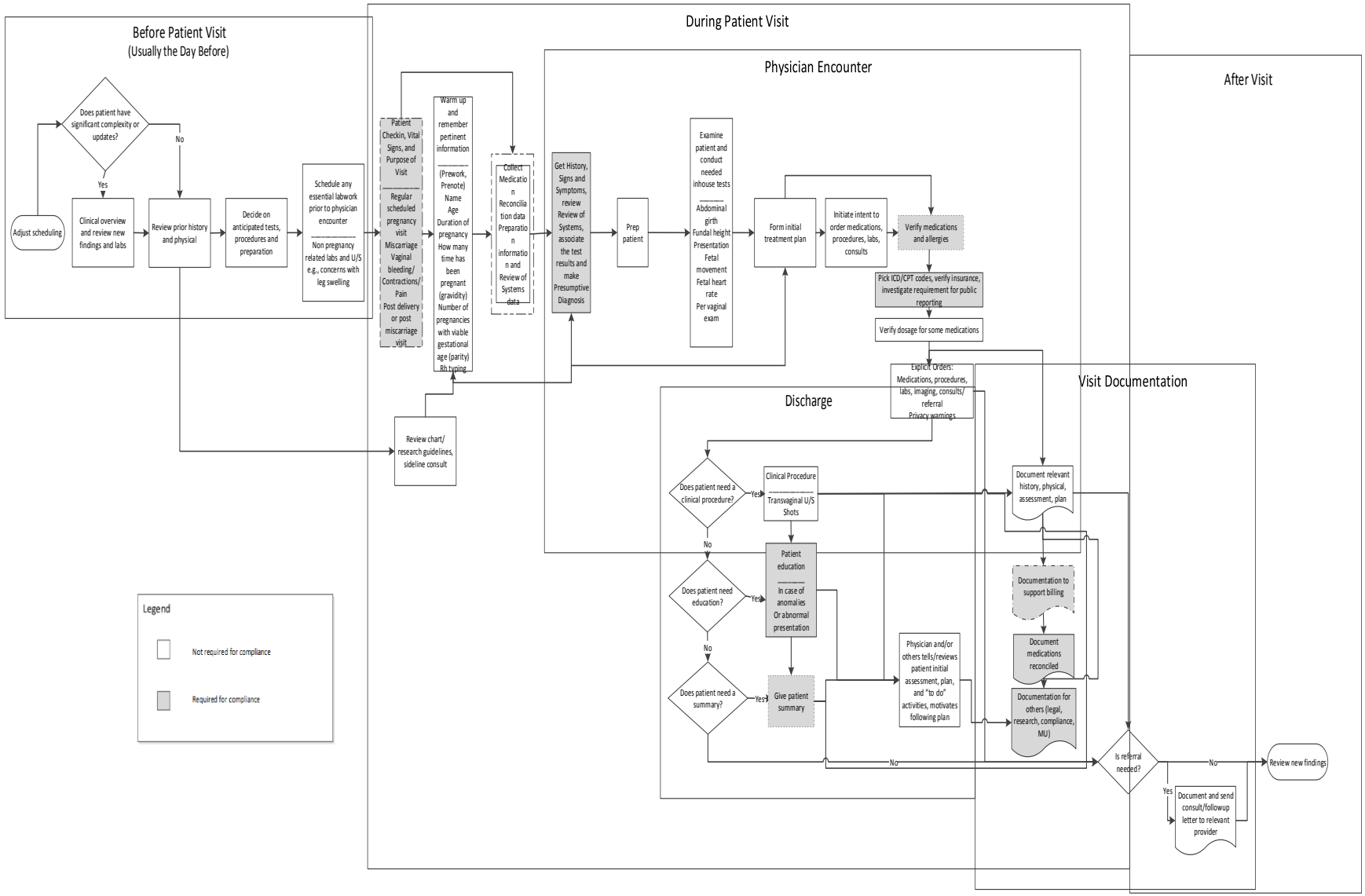

Figure 3. Process map for activities conducted with the EHR during a returning patient pregnancy visit in Ob-Gyn
(*Tip:* Printing this page on a paper of size A3 or larger provides legibility to read the contents)

3.B.2. Reminding the physician of planned tasks to accomplish during a patient visit

It would be useful in Ob-Gyn to have the EHR support remembering tasks which are anticipated to occur during a visit based upon knowledge of the specialty care area, the type and timing of the visit, and ideally patient-specific factors. An example would be having an annual gynecological check-up visit template. This template could sequence planned activities, thereby serving like a reminder checklist, as well as generate draft order sets and draft documentation that is modified by the provider during the visit. With a paper-based system, for example, if you anticipated that a patient would need a PAP smear and associated lab orders, you could fill out the appropriate paper form the night before, as well as portions of an encounter form. In the event that a patient did have abnormal findings to discuss during a visit, having a reminder of the need to discuss these on a patient summary display would be valuable when reviewing the summary the night before, immediately prior to, and/or during a visit with a patient.

3.B.3. Integrating personal health record data, patient portal information, and patient entered information

As more patients take advantage of the opportunity to view, download, and enter information personally into personal health records, portals, kiosks, and phone-based applications, it would be useful to integrate this information directly into the relevant portion of the patient chart. Due to the variable health literacy of patients, particularly with respect to the specialty care area knowledge, this information should be displayed differently, such as a "comment" in a margin or upon roll-over of the relevant information along with information about who entered the comment and when. If the provider chooses to accept the change, the "accept change" paradigm might be employed for chart information that can be modified by the provider.

3.B.4. Co-signing of ancillary support notes and findings

In specialized care areas, there are often specialized ancillary support staff who do and document important care activities, but often are not able to sign their own notes. Supporting co-signing is an important feature for EHRs for this purpose. An Ob-Gyn assistant does and documents clinical tasks such as collecting vital signs, collecting urine and blood samples, preparing equipment, preparing the patient, operating ultrasound and X-ray machines, and relaying medical information and instructions to patients.

3.B.5. Integrating previously entered data into the current visit

In specialized care areas, there are often unique data elements which are only typically accessible in notes sections of EHRs. Having the ability to see trends in these data would be useful in detecting clinical issues and monitoring change. In addition, there are some data that are important but do not change frequently, if at all. Having this information available without needing to enter it again would increase efficiency. Examples of information to integrate from previously entered data for Obstetrics care include fundal height, gestational age, last normal menstrual period.

3.B.6. Multiple simultaneous patient evaluations

In specialized care areas, the unique knowledge provided by a physician with extensive knowledge in a subfield of medicine is typically accessed in an economical and efficient fashion by having multiple simultaneous patient evaluations occurring in parallel. Therefore, restricting physicians to having one patient chart open at a time might increase the chances of completing all planned activities and documentation without additional memory support. On the other hand, the risks of entering data on the wrong patient are higher when there are multiple patient charts open without additional safeguards such as having an interim state between "closed" and "open" for a chart such as "waiting for additional care". For the specialty care areas, there is predictability of transitions in workflow by providers between patients requiring ongoing same day work, and knowledge about these transitions could be used to provide additional safeguards to reduce the risk of wrong patient errors. For example, times when the physician would likely leave the room to interact with another patient but then later return to finish a care

episode during Gynecological care include prior to the physical examination while the patient is getting undressed, after the physical exam and before the physician discusses the findings and concludes the visit.

3.B.7. Hands-free interaction with the EHR during procedures

During any outpatient care visit, there is often a physical examination when the provider would benefit by interacting "hands free" with the EHR. The benefit of having hands-free support is higher for some aspects of ophthalmological care. In particular, enabling voice-activated documentation of findings would be beneficial during the exam. This type of support is not easily provided with paper-based systems, where typically another person would document findings real-time during an examination which requires extensive use of the hands and a high memory requirement for detailed findings. Other specialty care areas with similar needs likely include physical therapy, occupational therapy, and dental care. Although rare, there are instances in Gynecological care where hands-free interaction would be helpful. In particular, a patient exam using a speculum for patients with abnormal pap smears can include detailed documentation requirements while the physician's hands are busy and the patient is in medical stirrups, and in some organizations includes taking images that are included in the EHR. Interestingly, the use of medical scribes was reported to be more common in gynecological than obstetric care by one physician at one hospital. Hands-free interaction is particularly important when reduced physical interactions with keyboards and screens will reduce the chances of infection.

3.B.8. Integrating information from specialized devices, software, data repositories

In specialized care areas, there are frequently specialized devices, software, and data repositories which are currently poorly integrated with most EHRs. Some integration is particularly challenging due to the size of the files (movies, radiology images, pathology images), in which case integration of reports describing findings from those data would be helpful. Similarly, integrated applications which reduce the size of files by reducing the data, such as by only viewing a single image through a section of tissue, may not provide adequate support for high quality clinical care. Specifically, most EHRs currently available lack the ability to do at least one of the following for at least one of these areas:

1) Display and manipulate data in a structured format. Data can be analog or digital measurement, analog or digital output, or electronic of mechanical. Output from devices or software can be images, movies, discrete data, graphs, or reports. Output from humans could be interpretations of analog data, digital data, film, paper strips from cardiac or ventilation sensors, or faxes from specialists.
2) Have a dedicated data field for clinically important elements
3) Enable annotation of data in a data field
4) Include images or "strips" in the original format (e.g., CIF, DICOM, TIFF, JPG)
5) Support drawing in freehand format on images
6) Include or link to data in other formats (PDF, TIFF, other outputs)
7) Highlight/emphasize data to display at the top level screen view (highlight an allergy on an overview display)
8) Supporting graphing data to detect trends over time including quantitative associated image data
9) Supporting search of text in reports
10) Have the option to store the output from the acquisition device directly in the EMR without being dependent on an active link
11) Have the option to store the raw output directly in the EMR without being restricted to device report summaries
12) Have the option to use standardized clinical data acquisition device associated workflow such as the Integrated Health Enterprise

In Obstetrics care, fetal monitor strips display the fetal heart rate graphed over time, blood pressure readings are graphed over sequential visits, images from an ultrasound machine are viewed to aid

diagnosis and treatment planning, as are images or movies (DICOM) from a fetal echocardiography machine.

3.B.9. Grouping conceptually related items with different formats (e.g., CIF, image, scanned image, fax, PDF, searchable text, structured data), particularly redundant data

For outpatient care settings which are not directly integrated into a large hospital system with a single organization for test results, it is typical to use multiple organizations to provide laboratory, radiology, and pathology results. In some cases, identical data could be integrated into the chart in multiple formats, such as from a fax which is scanned into the system and a PDF file. When there are updates to the findings, then this also needs to be collated. Without having conceptually related groupings, there is a risk of failing to find important information or important updates to information. Therefore, having all items related to a particular lab order in one unit would be extremely beneficial, particularly when some of the data are redundant, except for the formatting of the information.

3.B.10. Locating original images on image acquisition devices when viewing electronically stored images

Images are centrally important in many aspects of healthcare. In some cases, it is critical to view images in their original format, such as chest x-rays, in order to identify clinically relevant phenomena. Supporting the ability to easily locate original images in a different format from electronically stored images would be extremely useful and increase the efficiency of workflow. Chest x-rays are important in any specialty. Specialty-specific images include fetal monitor strips displaying the fetal heart rate graphed over time, images from an ultrasound machine, and images or movies (DICOM) from a fetal echocardiography machine.

3.B.11. Graphing data over time to identify patterns and trends, including extracting data from devices

A fundamental need when working with quantitative data is to visualize patterns and trends in data, which typically indicate a change in a clinical condition. Having the ability to view tables and graphs is centrally important to recognizing patterns. Ideally, this ability would include structured data extracted from devices such as DICOM images from a fetal echocardiography machine. In some cases, the graphing capability existed, but accessing it was not done because the judgment was that the process was too inefficient and that there was poor interface usability. Particularly important data to visualize in Obstetrics are the fetal heart rate over time, fundal height, and cervical length in ultrasound images at subsequent visits.

3.B.12. Providing medical history tailored to the specialty area

The specialist care providers prefer that a default view of patient history be one that is tailored to their specialty care area. Although this information is often theoretically available in a tailored view, reducing the number of "clicks" to have it automatically available would make it easier to use on a routine basis in an efficient manner. Particularly important information to have "at a glance" on one page for Obstetrics care is patient age (particularly if the patient is over 35 years old, which is an "advanced maternal age"), how many times the patient has been pregnant, visit type, how many weeks pregnant the patient is, today's weight, blood pressure and pulse, if a patient lacks the Rh antigen (e.g., is Rh-negative), labs or consult notes since the last visit, summary of lab data, fundal height data, vital sign data, problem lists specific to the specialty care area, and whether the patient had flu and TDAP vaccinations in prior pregnancies.

3.B.13. Providing a draft order set that can be modified during the visit which is tailored to diagnostic information and other patient data

There are many benefits to sending orders during the exam if it can be made efficient, including the opportunity to ask patients and caregivers information during the ordering process. Based upon the

diagnostic information and other patient data, such as gestational age, the likely set of orders that will be made is highly predictable for most patients. Nevertheless, physicians need to ensure that there are not exceptions which require changing the orders. Therefore, having a draft order set provided would be beneficial. This type of functionality is particularly helpful when there are multiple options that look similar but where one is preferred.

3.B.14. Verifying that recently changed insurance and regulatory requirements are met when ordering and interpreting diagnostic tests

When procedures or medications cost thousands of dollars, it is important to verify that insurance requirements are met during the ordering process. Providing EHR functionality to ensure that these requirements are met during the ordering process would be useful if the functionality has the ability to update the information on a frequent basis.

3.B.15. Providing quick access to short summary syntheses of findings from recent research

In all care areas, there is always a need to take advantage of recent research to provide high quality care. Providing links to published studies might be helpful, but unlikely to be used in the context of a time-constrained visit. Having quick access to a short excellent summary that synthesizes a number of findings would be beneficial.

3.B.16. Selecting correct administrative codes (ICD, CPT) for the visit documentation

Every provider's note on every patient is required to support an accurate selection of a diagnostic code from the International Classified of Diseases (ICD) and procedure code from the Current Procedural Terminology (CPT) code set in order to receive reimbursement for care. Providing support to ensure this requirement is met would likely create a greater opportunity for clinicians to focus more on the clinical aspects of interacting with a patient. It would be extremely useful to support transitions between code sets such as ICD-9 to ICD-10. For example, the ICD-9 code for Macular Degeneration Not Otherwise Specified is 362.50. With ICD-10, the same disease is coded as H35.30.

3.B.17. Selecting patient's current insurance plan's pharmaceutical formulary

During the ordering process, medication orders need to be restricted to the patient's current insurance plan's most recent pharmaceutical formulary in order to meet insurance requirements and determine the cost of the medication when potentially expensive. Providing support for this requirement would allow providers to focus more on clinical aspects of the ordering process. By integrating the details of the patient's pharmacy benefits, the provider and patient through shared decision making can decide on which medication option to choose. If a subsequent determination by the insurance is required, the delayed decision should be placed in a queue that can subsequently be completed to optimize compliance, efficiency, and outcome.

3.B.18. Meeting medical necessity documentation for procedures, medications, transportation, convalescence, or work restriction

Providers are in some cases required to provide documentation to meet legal requirements for documentation. Examples include documentation for procedures, medications, transportation, convalescence, or work or driving restrictions. Providing support would reduce the complexity of ensuring that requirements are met efficiently and accurately and help optimize outcomes and compliance.

3.B.19. Meeting informed consent requirements with procedure specific details

Providers are required to obtain informed consent from patients for medical procedures. Having the ability for patients and caregivers to obtain this information prior to the visit would improve the ability for them to make an informed decision and to have an efficient visit and help optimize outcomes and compliance.

3.B.20. A holistic approach to the goal of optimizing patient compliance to scheduled follow-ups and needed medical regimen

Providing high quality care to patients is increasingly being defined to include applying evidence-based strategies to improve patient compliance to a treatment plan. Data in the electronic health record can help to inform a "learning health system" about what approaches to achieving patient compliance are best suited to patient cohorts based on an individual patient's historical compliance as well as generalized ethnic and other compliance information such as family caregivers' preferences.

3.B.21. Integrating surgical notes into the EHR

Surgical minor procedures in a clinic setting as well as more involved procedures in an ambulatory surgery center or a hospital need to be directly integrated into the patient's medical record in order to provide appropriate follow-up care.

3.C. Discharge

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs during the period at the conclusion of the visit (discharge). Opportunities for providing support during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

3.C.1. Informing patients about whether medications need to be obtained immediately following the visit

For some care situations, obtaining medications needs to be done immediately following the visit rather than the typical situation of within a day or two following the visit. Taking advantage of knowledge of the diagnosis and medication to highlight this need for patients would be useful. Supporting informing patients of this information, such as by integration into a printout received at the conclusion of the session, would be valuable.

3.C.2. Informing patients what to watch for and who to contact if particular events happen

After the visit, patients will occasionally need to contact a healthcare provider in the event that something unexpected or undesirable occurs. Including this information in a printout handed to the patient would be valuable.

3.C.3. Optional redaction of particularly sensitive patient information from after-visit summaries

In all care settings, patient information has the potential to be highly sensitive, including mental health diagnoses, infectious diseases, obesity or drug use, genetic information, and information which could impact a professional or personal reputation. Nevertheless, Ob-Gyn care frequently has documentation which is highly sensitive for the majority of patients, or which is potentially problematic when shared with caregivers, family members, or friends. Examples include history of pregnancies, abortions, miscarriages, infertility, sexually transmitted diseases, drug and alcohol use, spousal abuse during pregnancy, results of mandatory drug testing, identities of donors for sperm and eggs, and evidence that the parent is not the genetic father of a child. In situations where patients wish to explicitly redact particular information from After Visit Summaries or other paperwork that is routinely printed or disseminated in the presence of caregivers, it would be extremely helpful to be able to support this option. Given that providing this summary is a requirement for Medicare reimbursement, having an option to print a redacted After Visit Summary at the completion of the visit would be particularly helpful. A related issue is that patients may not wish to give personally identifiable information associated with their patient data. It would be extremely useful for the EHR to permit anonymization of patient data per patient's wishes.

3.C.4. Supporting optimization of patient compliance

Patients may need to be on a certain medication regimen or have certain procedures or tests performed. There should be queue management including automated contacting of the patient when there is no evidence that medications have been filled or tests have been performed. If critical care steps haven't occurred, as evidenced by lack of receipt of pharmacy evidence that a medication for a particular patient was dispensed, or from imaging centers that a particular imaging test has not been performed, the lack of compliance can be escalated as warranted to automatically contact the patient and subsequently involve support staff or provider. The queue should be alterable to not overwhelm the user with queue fatigue and should be alterable to specific patient's needs, reliability of receipt of external data, and provider workflow.

3.D. Documentation

Documentation of a visit is not conducted in any particular step in the workflow. Some specialists begin documentation prior to the visit and make all orders and complete all documentation with the patient. Some complete documentation in-between patients or during breaks. Some complete documentation the night after a visit was completed. Documentation elements include:

- Relevant history, physical, assessment, and plan;
- Detailed descriptions to 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.

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 during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

3.D.1. Correcting auto-generated information which is inaccurate

All of the healthcare providers had experiences with inaccurate information which was auto-generated from devices or software packages for a variety of reasons. Unsurprising sources of inaccuracies included sensor failures, missing data, "wrong patient" data, and situations where nurses are aware of a need to update a problem list but are not authorized to do (e.g., the nurse can order antibiotics based upon a urinalysis result based upon a physician order, but is not allowed to add UTI to the problem list). Not having the ability to correct inaccurate information is potentially dangerous when providing care. Workarounds such as creating an addendum to a note stating that a patient has an inaccurate diagnosis listed are likely not effective, and certainly are suboptimal. The auto-generated notes can sometimes only be viewed when a legal discovery request occurs sometimes providing surprising auto-generated information that is incorrect. Viewing all entered and auto-generated data associated with a patient visit should occur prior to having the data enter the medical record.

3.D.2. Drafting documentation and encounter forms which are tailored to diagnostic information

In Gynecological care, there are predictable patterns of care which can form the basis for draft encounter forms and other documentation facilitation. In addition, in Ob-Gyn, there are indicators that could be taken advantage of relating to the certainty that plans will go as expected. For example, the annual visit is likely to follow a predictable routine unless there are chronic problems such as hypertension, or diabetes, or past abnormal findings from PAP smears or endometrial biopsies.

3.D.3. Reducing logins and sign-offs for multiple software packages and devices used to accomplish related functions

In specialty care, niche software and devices are frequently employed that are not used or available in inclusive EHRs. Having support for a single login process, reducing challenge questions and other keystrokes during logins, and reducing additional logins following automatic sign-offs would be beneficial. There are some unique elements to these needs for Obstetrics care. The additional login and sign-off requirements were estimated by one Ob-Gyn physician to add 1.5 hours to an 8 hour day when the visits were scheduled for 15 minutes each. One obstetrician reported that a staff member opened four EHRs on each computer in each exam room with the patient's information pulled up simultaneously before he entered the room to enable a more efficient visit and to avoid "wrong patient" errors. Another obstetrician reported having to copy and paste information from an ultrasound software package into the EHR or else no longer have access to it one or two weeks later when the patient returned for a follow-up visit. In addition, there were separate passwords for the EHR, one other software, and the fetal strips monitoring software, some of which required challenge questions in addition to a login process. The access times to the other software could theoretically be inspected during a lawsuit to determine if a note was documented before the information was accessed, which could add the need for additional logins if a task took long enough to create an automated sign-out. For example, in order to have a compliant sequence for a non-stress test, the physician would access the software and check the tracing. Then the findings would be documented in a note in the EHR, including the specific issues, and then the chart needs to be signed off on within 48 hours. In order to accomplish this goal, HIPAA privacy and security rules need to be followed in order to protect Personal Health Information (PHI) data and mitigate the risks of identity theft.

3.D.4. Annotating documentation by patients and caregivers in a progress note

More patients are expected in the future to take advantage of the so-called 'blue button' opportunity to view their progress note documentation. The demand will likely increase to correct misinformation or otherwise annotate the note. Because the patient is not a healthcare professional at the organization, it is likely inappropriate to use the workflow for corrections to the health record from professionals. Therefore, this information should be displayed in a different fashion, such as a "comment" in a margin or upon roll-over of the relevant information along with information about who entered the comment and when. One provider stated that having physicians engage in discussions about aspects of the chart, including requests from patients to explain portions of a note to them, would be an undesirable outcome due to the additional workload burden. Therefore, the design would likely need to minimize the frequency of "back and forth" communications between physicians and patients about annotations and progress note information.

3.D.5. Having additional protections on personal health information

Although current examples of issues with personal health information being disseminated beyond the wishes of patients and caregivers were not commonly observed, several of the providers expressed concerns about the potential for this to occur and described individual anecdotes as "proof of concept" that issues could arise. Data repositories are being generated with access being provided to non-traditional users, such as schools in order to verify immunizations. In general, it is anticipated that a subset of patients will feel strongly about the desire to protect a particular data element from use in population health research or other population-based initiatives (e.g., marketing studies). Providing electronic support for "opting in or out", similar to options for organ donation programs, would be an interesting area for consideration in the next generation of EHRs. Possible areas might include "Do Not Resuscitate" advance directives or not allowing blood transfusions for religious reasons (e.g., Jehovah's witness patients). Accomplishing this objective will likely require negotiations between stakeholder groups with differing, and potentially conflicting, perspectives in this relatively uncharted territory.

4 Process Maps and Workflow Redesign Opportunities for Ophthalmology

Steps in the workflow are visualized in Figure 4 as an overview at a high level of detail for Ophthalmology for EHR interactions related to an established patient's return visit with the specialist care provider in an outpatient setting. These steps are similarly grouped as:

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

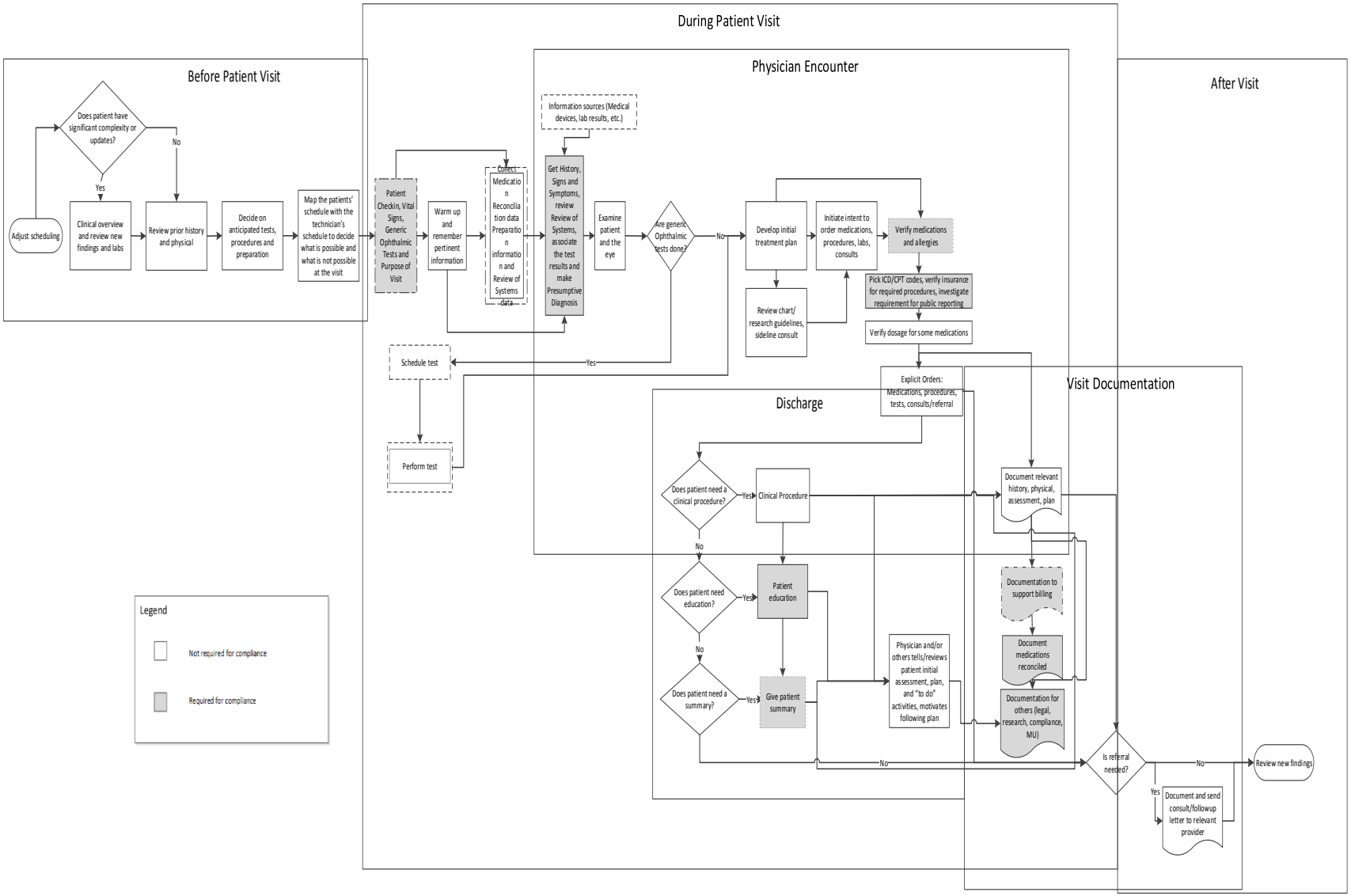

Figure 4. Overview process map for EHR use related to returning patient visit in Ophthalmology
(*Tip:* Printing this page on a paper of size A3 or larger provides legibility to read the contents)

4.A. Before the patient visit

In Figure 5, the process steps related to activities occurring with the EHR before the visit are displayed. These are:

- Adjust scheduling in order to balance workload demands and take into account predictions and updates about how long types of patients will take and meet the unexpected urgent needs of scheduled and unscheduled patients,
- Clinical overview and review new findings and labs for patients with significant complexity and updates,
- Review prior history and physical for all patients,
- Decide on anticipated tests, procedures, and preparation, and
- Map the patient's schedule with the technician's schedule to decide what is possible and not possible to do at the visit.

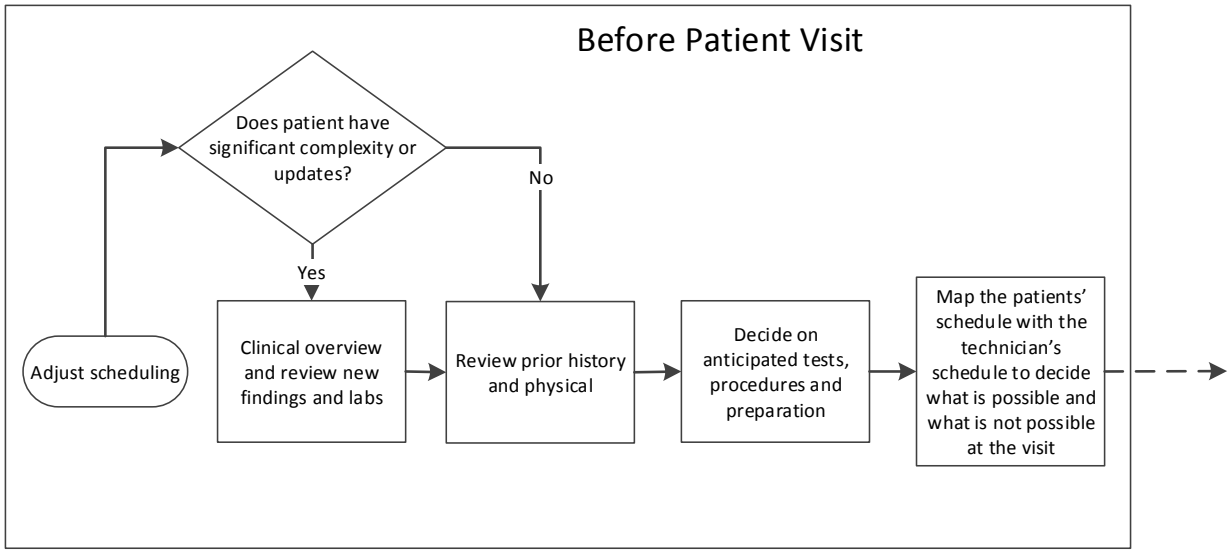

Figure 5. Process map for activities conducted before a returning patient visit with the EHR for Ophthalmology

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Many of these were decision support enhancements based upon information about the specific patient which would be available in the EHR. Opportunities for providing support during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

4.A.1. Reducing the risk of missing a target time interval to provide optimal care actions due to scheduling issues

In Ophthalmology, there are time intervals to provide optimal care. When patients are scheduled outside of that window, the care is less than optimal, and in some cases, there are patient safety concerns that arise. For example, an intravitreal injection of a medication is typically given to treat macular degeneration during recommended time intervals, on a recurring basis. It is not standard practice to provide this injection too soon after the last injection. If the time interval between injections is more than the suggested interval after the prior injection, the eye disease may get worse, leading to a possibly irreversible loss of visual acuity. Patients who are at particularly high risk for failures to appropriately schedule a visit include patients who have dementia, memory loss, multiple medical problems, live in

more than one location (such as a college student or retiree with a winter and summer home), or have a history of missing scheduled appointments or failing to schedule appointments. Optimal compliance and persistence with a particular treatment regimen will lead to optimal outcomes. The EHR could use the patient's diagnosis, last visit, and recommended time interval for the next step in the care plan, and likelihood of missing an appointment to provide decision support for the scheduler or physician. Additionally, the EHR could communicate directly with the patient, such as by contacting the patient by email to remind him or her to schedule a care action within a particular time window, and escalating the communications when the anticipated visit is not scheduled as expected. Visualizations which highlight appointments that are past the recommended window or alerts about patients who have not yet been scheduled in the recommended timeframe for a recommended care action could reduce the risk of missing the target time interval. Similarly, patients who have reached stability can have increased flexibility in scheduling, including being deferred to longer intervals if a patient with more urgent needs has to be accommodated during scheduling. For example, a patient with Age-related Macular Degeneration (AMD) typically requires monthly monitoring during a return visit. If a patient has not received an injection in the last six visits, then this interval can be extended to 8 weeks to 12 weeks.

4.A.2. Distinguishing between patients with a very high likelihood of getting a particular treatment from patients who are less likely to get the treatment

In Ophthalmology, there are predictable patterns of care which can form the basis for visit checklists, order sets, encounter forms, and other documentation facilitation. In addition, there are indicators that could be taken advantage of relating to the certainty that plans will go as expected. For example, annual eye screenings follow a predictable routine unless there are chronic problems such as glaucoma, or diabetes, or past abnormal findings from eye examinations. For patients with diagnoses specific to the field, there are predicted treatment actions that are taken with a high certainty. Nevertheless, there are known exceptions to how these treatments are conducted, and alerting physicians in a prominent fashion to these factors would be highly useful. For example, stroke specialist may have written explicit instructions not to give an intravitreal injection to a patient with macular degeneration for a period of time after a stroke.

4.A.3. Alerting physicians to information about patients that informs how to conduct a patient visit

In Opthalmology, providers employed techniques to provide alerts when opening a patient's chart that were helpful to tailoring the conduct of a patient visit. In most cases, these techniques were "positive workarounds" in that they used EHR functionality which was not designed for that purpose, and thus the use was less than optimal, if only because the other intended use was affected. Examples include identifying patients with special needs, such as prisoners, autistic patients, patients requiring interpreters, and patients who are only willing to receive care from one particular provider. Having this information incorporated into a tailored specialty care overview display for multiple patients scheduled for that day would eliminate the need to use "workaround" pop-up alerts or problem list items.

4.A.4. Integrating medication information from pharmacies, hospitals and insurance formularies into the EHR

Obtaining accurate information about what medications a patient has been taking can be a challenging process for many reasons. Although there can be reasons for why the information might be incomplete or inaccurate, one of the more trusted sources of information is the pharmacy where a patient obtains the medication and the hospital where medications were administered during an inpatient stay. Insurance formularies and prescription drug benefits are important sources of information because this has the preferred list for what the patient has available and must pay to receive medications. Having this information integrated directly into the EHR would be beneficial when eliciting and verifying information about medications from patients and caregivers for both clinical and reimbursement purposes.

4.A.5. Verifying that insurance requirements are met during the scheduling process

In Ophthalmology, some elements of the treatment plan can be determined based upon insurance requirements. When procedures or medications cost thousands of dollars, it is important to verify that insurance requirements are met during the scheduling process. Providing EHR functionality to ensure that these requirements are met during the scheduling process would be useful in order to allow the specialist physicians to focus more on the clinical aspects of the visit. For example, an intravitreal injection for macular degeneration costs thousands of dollars for the medication, and thus the ability for insurance to pay for it needs to be incorporated into the scheduling process. In addition, there can be restrictions on when actions are performed in order to obtain reimbursement. For example, Medicare limits the number of tests that can be done in a single visit, such as not reimbursing when a visual field test and an optic nerve scan are conducted on the same day.

4.A.6. Flexible real-time assignments of different staff to tasks across multiple patients simultaneously

There can be a high variability in terms of whether ancillary staff or specialist physicians do certain tasks. The flow of the day is improved when the assignment of tasks is flexible based upon bottlenecks that emerge during the day. Having the ability to flexibly allocate and re-allocate assignments would be useful. Flexible allocation requires that the personnel assigned to meet requirements for reimbursement, accreditation, and for other entities are supported in the sequence of events (e.g., ordering in the chart can be required to be conducted before the procedure), documentation of interpretations in the correct portion of the chart by the appropriate person, and required sign-offs by primary care providers. Examples where specialized support staff can be assigned tasks in vision care include an optical coherence tomography (OCT) imaging technique of the eye.

4.A.7. Usable access to patient data from diverse hardware platforms, including mobile devices

Specialty care providers may work in a variety of clinical settings, even within a single day when time spent going from one setting to another can be used to prepare for patient visits. In different settings, there might be different platforms which are required to be used by the relevant organizations. In addition, requests for care may come outside of scheduled clinic hours, when mobile devices need to be used to respond to care requests. Therefore, usability of software needs to be achieved from diverse hardware platforms, including mobile devices and other platforms with limited screen size and no keyboard or touch screen interactions.

4.B. During the patient visit

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

- Check in patient, obtain vital signs or eye vital signs like visual acuity and intraocular pressure (per eye) 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, do eye examination (i.e., physical examination)
- Form initial treatment plan,
- Review chart/research guidelines, informal consult,
- Initiate intent to order medications, labs, procedures, imaging procedures, 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,

- Verify laterality (right eye or left eye) for eye procedures,
- Explicit orders for medications, procedures, labs, imaging, consults/referral,
- Do 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,
- Correct documentation to support billing including signing scribe entered information,
- Correct document medications reconciled, and
- Correct documentation for others, e.g., legal, research, compliance, Meaningful Use.

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, Ophthalmology technician, 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 when the provider:

- 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.

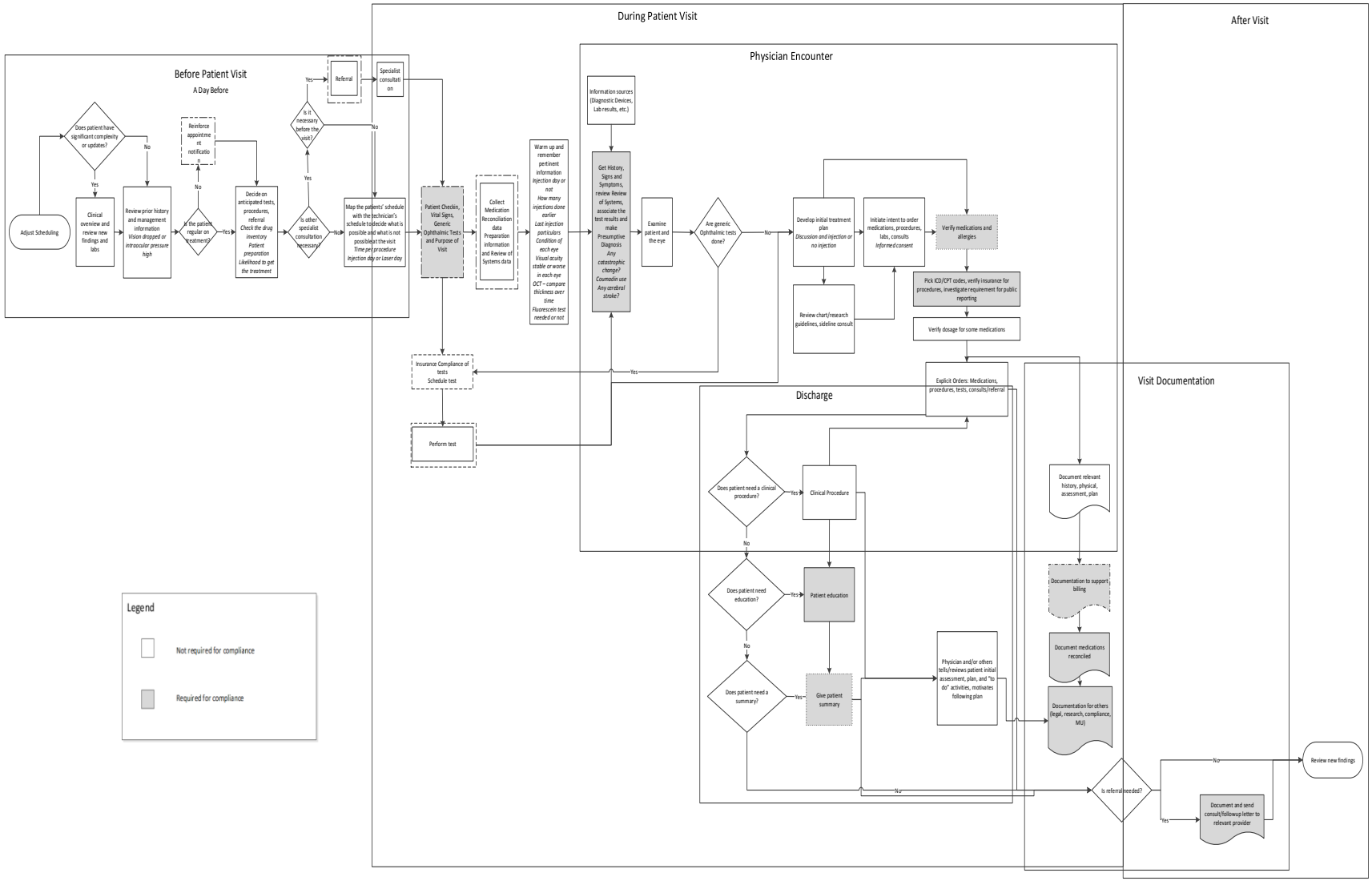

Figure 6. Process map for activities conducted with the EHR during a returning patient with Age-related Macular Degeneration in Ophthalmology

Age-related macular degeneration was purposely picked as an example due to its relatively low complexity, which facilitated making a fairly simple process map. The return visit for this type of disease could be characterized as following a pre-planned procedure for treatment where you are mainly checking to see if there are any exceptions to the common situation where you would need to modify the plan. The sequence is almost robotic in getting an image, reviewing it, possibly getting an OCT image, and then providing an eye injection. In comparison, a return visit for a uveitis patient is a much more complex process. With uveitis, there is an ongoing search, often for years, to explain symptoms and a definitive explanation may never be found. Therefore, the step of "Get history, signs and symptoms, review of systems, make working or presumptive diagnosis" is a primary focus and highly cognitive challenging. It is critical to employ subtle co-construction of meaning between the physician and the patient where the patient initially describes symptoms and changes in symptoms, the physician does targeted queries that are based upon a deep knowledge of the subject domain. There are "rules of thumb" about common queries such as redness, pain, light sensitivity, and change in vision, but there are frequent deviations from what might be implemented using a "checklist" approach. Similarly, the step of "Form initial treatment plan" has many more possibilities than with macular degeneration. In addition to having a larger set of possible treatments, there is a greater need to educate the patient on when to seek medical help for particular symptoms. In some cases, there are catastrophic risks with irreversible vision loss that require patients to advocate for care when certain symptoms occur, even if there is no scheduled or planned visit with the specialist.

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 during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs in Ophthalmology care are:

4.B.1. Displaying summary information in a format which matches how specialist physicians were trained to recognize patterns

Specialist physicians have standardized specialized formats for viewing data within their fields. Detecting patterns and trends using these formats is central to diagnosis and treatment. In Ophthalmology , there is specialized iconography and abbreviations that are used to document the examination findings which is not commonly used in EHR systems. Also, the equivalent of systemic vital signs such as visual acuity and intraocular pressure are frequently not optimally aggregated or displayed across multiple visits. Additionally, it is standard to refer to right eye (oculus dexter – OD) first and the left eye (oculus sinister - OS) second. The laterality is from the perspective of the patient, not from the perspective of someone looking at the patient. With software upgrades for some EHRs, the display of "left eye" and "right eye" has inadvertently been changed to the perspective of a provider viewing a patient, causing confusion and can be dangerous for patients because clinical personnel have been trained to the patient-centric standard.

4.B.2. Reminding the physician of planned tasks to accomplish during a patient visit

It would be useful to have the EHR support remembering tasks which are anticipated to occur during a visit based upon knowledge of the specialty care area, the type and timing of the visit, and ideally patient-specific factors. For example, there are some diagnoses, such as macular degeneration, that require highly standardized care for the vast majority of patients. Taking advantage of knowing what actions are expected in the design of supporting displays or templates would be useful. Highlighting patients for whom the routine approach would be altered is also extremely valuable, such as a patient who has experienced a recent stroke and thus should not receive an intravitreal injection during the visit. Also, reminders regarding obtaining same-day images prior to the provider's examination is important for clinic workflow. In more complex and varied care such as for patients with uveitis, aggregating important historical events such as prior and current medications; and, these patients should have laboratory analysis reminders within specific time intervals (if not being co-managed with other physicians). Also,

facilitating what elements of the work-up and treatment had been performed in relation to uveitis activity to reduce cognitive workload will help achieve optimal outcomes.

4.B.3. Integrating personal health record data, patient portal information, and patient entered information

As more patients take advantage of the opportunity to view, download, and enter information personally into personal health records, portals, kiosks, and phone-based applications, it would be useful to integrate this information directly into the relevant portion of the patient chart. Due to the variable health literacy of patients, particularly with respect to the specialty care area knowledge, this information should be displayed differently, such as a "comment" in a margin or upon roll-over of the relevant information along with information about who entered the comment and when. If the provider chooses to accept the change, the "accept change" paradigm might be employed for chart information that can be modified by the provider.

4.B.4. Co-signing of ancillary support notes and findings

In specialized care areas, there are often specialized ancillary support staff who do and document important care activities, but often are not able to sign their own notes. Supporting co-signing is an important feature for EHRs for this purpose. An Ophthalmic technician performs and documents clinical tasks such as measuring visual acuity, instilling ocular medications, obtaining historical information, and helping instruct the patient regarding medications, tests, and procedures

4.B.5. Integrating previously entered data into the current visit

In specialized care areas, there are often unique data elements which are only typically accessible in notes sections of EHRs. Having the ability to see trends in these data would be useful in detecting clinical issues and monitoring change. In addition, there are some data that are important but do not change frequently, if at all. Having this information available without needing to enter it again would increase efficiency. Examples of information to integrate from previously entered data for Ophthalmology include: per eye visual acuity, visual acuity with both eyes and with or without correction, intraocular pressure, cup to disk ratio, and corneal topography.

4.B.6. Multiple simultaneous patient evaluations

In specialized care areas, the unique knowledge provided by a physician with extensive knowledge in a subfield of medicine is typically accessed in an economical and efficient fashion by having multiple simultaneous patient evaluations occurring in parallel. Therefore, restricting physicians to having one patient chart open at a time might increase the chances of completing all planned activities and documentation without additional memory support. On the other hand, the risks of entering data on the wrong patient are higher when there are multiple patient charts open without additional safeguards such as having an interim state between "closed" and "open" for a chart such as "waiting for additional care". For the specialty care areas, there is predictability of transitions in workflow by providers between patients requiring ongoing same day work, and knowledge about these transitions could be used to provide additional safeguards to reduce the risk of wrong patient errors. For example, times when the physician would likely leave the room to interact with another patient but then later return to finish a care episode include after a patient has received eye drops which require time to achieve efficacy prior to an examination.

4.B.7. Hands-free interaction with the EHR during procedures

During any outpatient care visit, there is often a physical examination when the provider would benefit by interacting "hands free" with the EHR. The benefit of having hands-free support is higher for some aspects of Ophthalmological care. In particular, enabling voice-activated documentation of findings would be beneficial during the examination. This type of support is not easily provided with paper-based systems, where typically another person would document findings real-time during an examination which

requires extensive use of the hands and a high memory requirement for detailed findings. Other specialty care areas with similar needs likely include physical therapy, occupational therapy, and dental care. There are some extensive eye examinations when there are many findings to remember to document while using both hands. During motility examination of eye movements multiple prisms may need to be held by the examiner. In addition, a peripheral retinal examination requires a condensing lens in one hand and a scleral depressor in the opposite hand. Interacting with the EHR during these examinations is extremely difficult, and secondary in priority to the use of other specialized eye equipment. Hands-free interaction is particularly important when reduced physical interactions with keyboards and screens will reduce the chances of infection.

4.B.8. Integrating information from specialized devices, software, data repositories

In specialized care areas, there are frequently specialized devices, software, and data repositories which are currently poorly integrated with most EHRs. Some integration is particularly challenging due to the size of the files (movies, radiology images, pathology images), in which case integration of reports describing findings from those data would be helpful. Similarly, integrated applications which reduce the size of files by reducing the data, such as by only viewing a single image through a section of tissue, may not provide adequate support for high quality clinical care. Because images and reports from an Ocular Coherence Tomography (OCT) device or raw data from visual field devices need to be easily accessible for the correct patient during the visit, typically the Ophthalmologist will currently have multiple windows from networked devices like the OCT device of the Fundus cameras open along with the EHR while seeing the patient. Specifically, EHRs currently available lack the ability to do at least one of the following for at least one of these areas:

- Display and manipulate data in a structured format. Data can be analog or digital measurement, analog or digital output, or electronic or mechanical. Output from devices or software can be images, movies, discrete data, graphs, or reports. Output from humans could be interpretations of analog data, digital data, film, paper strips from cardiac or ventilation sensors, or faxes from specialists.
- Have a dedicated data field for clinically important elements
- Enable annotation of data in a data field
- Include images or "strips" in the original format (e.g., CIF, DICOM, TIFF, JPG)
- Support drawing in freehand format on images
- Include or link to data in other formats (PDF, TIFF, other outputs)
- Highlight/emphasize data to display at the top level screen view (highlight an allergy on an overview display)
- Supporting graphing or putting data into a table or other structured format to detect trends over time including quantitative associated image data
- Supporting search of text in reports
- Have the option to store the output from the acquisition device directly in the EMR without being dependent on an active link
- Have the option to store the raw output directly in the EMR without being restricted to device report summaries
- Have the option to use standardized clinical data acquisition device associated workflow such as the Integrated Health Enterprise

4.B.9. Grouping conceptually related items with different formats (e.g., CIF, image, scanned image, fax, PDF, searchable text, structured data), particularly redundant data

For outpatient care settings which are not directly integrated into a large hospital system with a single organization for test results, it is typical to use multiple organizations to provide laboratory, radiology, and pathology results. In some cases, identical data could be integrated into the chart in multiple formats,

such as from a fax which is scanned into the system and a PDF file. When there are updates to the findings, then this also needs to be collated. Without having conceptually related groupings, there is a risk of failing to find important information or important updates to information. Therefore, having all items related to a particular lab order in one unit would be extremely beneficial, particularly when some of the data are redundant except for the formatting of the information. An example would be to support grouping the relevant set of information for a patient with retinal vein occlusion to enable a physician to investigate the findings efficiently.

4.B.10. Locating original images on image acquisition devices when viewing electronically stored images

Images are centrally important in many aspects of healthcare. In some cases, it is critical to view images in their original format, such as chest x-rays, in order to identify clinically relevant phenomena. Supporting the ability to easily locate original images in a different format from electronically stored images would be extremely useful and increase the efficiency of workflow. Chest x-rays are important in any specialty. Specialty-specific images include images and reports from an Ocular Coherence Tomography (OCT) device, fluorescein angiograms, corneal topography, visual fields and autorefractor output.

4.B.11. Graphing of viewing formatted data (tables) over time to identify patterns and trends, including extracting data from devices

A fundamental need when working with quantitative data is to visualize patterns and trends in data, which typically indicate a change in a clinical condition. Having the ability to view tables and graphs is centrally important to recognizing patterns. Ideally, this ability would include structured data extracted from devices such as DICOM images from a fetal echocardiography machine and images from an Ocular Coherence Tomography (OCT) device. In some cases, the graphing capability existed, but accessing it was not done because the judgment was that the process was too inefficient and that there was poor interface usability. Particularly important data to visualize are intraocular pressure over time to determine how it interacts with medication changes, retinal nerve fiber layer changes over time, and retinal thickness measurements from an OCT device.

4.B.12. Providing medical history tailored to the specialty area

The specialist care providers would prefer that a default view of patient history be one that is tailored to their specialty care area. Although this information is often theoretically available in a tailored view, reducing the number of "clicks" to have it automatically available would make it easier to use on a routine basis in an efficient manner. Particularly important information to have "at a glance" on one page are the equivalent of "vital signs" for Ophthalmology, such as: intraocular pressure, visual acuity, and visual field output separated and grouped per eye.

4.B.13. Providing a draft order set to modify during the visit which is tailored to diagnostic information and other patient data

There are many benefits to sending orders during the visit if it can be made efficient, including the opportunity to ask patients and caregivers information during the ordering process. Based upon the diagnostic information and other patient data, the likely set of orders that will be made is highly predictable for most patients. Nevertheless, physicians need to ensure that there are not exceptions which require changing the orders. Therefore, having a draft order set provided would be beneficial. This type of functionality is particularly helpful when there are multiple options that look similar but where one is preferred. Examples include prescribing eyeglasses will be helped by knowing prior eyeglass prescriptions and previous refractions grouped per eye in a standardized format sphere, cylinder, prism, and for contact lenses knowing prior base curves, diameters, and powers. The eyeglass prescription determination will frequently occur early in the visit prior to fundus examination. For macular

degeneration with a choroidal neovascular membrane where it is planned to continue treatment, it is highly predictable that patients will receive an intravitreal injection during the visit.

4.B.14. Orders including requiring unique data fields for the specialty area

For specialty care areas, there can be unique data fields for orders. Examples include eye drop medications which need to specify which eye (right eye, left eye, or both eyes) and the number of drops (which frequently differ for one eye as compared to the other in certain diseases such as uveitis). For uveitis, there is often a long tapering regimen over weeks of less frequent administration of eye drops per day.

4.B.15. Verifying that recently changed insurance and regulatory requirements are met when ordering and interpreting diagnostic tests

When procedures or medications cost thousands of dollars, it is important to verify that insurance requirements are met during the ordering process. Providing EHR functionality to ensure that these requirements are met during the ordering process would be useful if the functionality has the ability to update the information on a frequent basis. In Ophthalmology, the cost of medications, such as those available treatments for "wet" macular degeneration, are often the most expensive part of care. For both patient and provider, anything that specifies the accurate actual cost to the patient at the time of the visit will streamline care and result in improved outcomes. In addition less expensive but important diagnostic tests such as an optical coherence tomography (OCT) imaging technique of the eye is an important diagnostic tool with insurance and regulatory requirements that frequently change. Although ideally it often would be most convenient for patients to receive tests on the same day, insurance rules frequently require the outpatient to return on multiple days and may not pay for more than one test per day. It would help the provider and patient plan for needed treatment by clarifying these restrictions at the time of the patient visit.

4.B.16. Providing quick access to short summary syntheses of findings from recent research

In all care areas, there is always a need to take advantage of recent research to provide high quality care. Providing links to published studies might be helpful, but unlikely to be used in the context of a time-constrained visit. Having quick access to a short excellent summary that synthesizes a number of findings would be beneficial.

4.B.17. Selecting correct administrative codes (ICD, CPT) for the visit documentation

Every provider's note on every patient is required to support an accurate selection of a diagnostic code from the International Classified of Diseases (ICD) and procedure code from the Current Procedural Terminology (CPT) code set in order to receive reimbursement for care. Providing support to ensure this requirement is met would likely create a greater opportunity for clinicians to focus more on the clinical aspects of interacting with a patient. It would be extremely useful to support transitions between code sets such as ICD-9 to ICD-10. For example, the ICD-9 code for spontaneous abortion is 634.00. With ICD-10, the code is O03.5.

4.B.18. Selecting patient's current insurance plan's pharmaceutical formulary

During the ordering process, medication orders need to be restricted to the patient's current insurance plan's most recent pharmaceutical formulary in order to meet insurance requirements. Providing support for this requirement would allow providers to focus more on clinical aspects of the ordering process. By integrating the details of the patient's pharmacy benefits as well as the costs with and without insurance coverage, the provider and patient, through shared decision making, can decide on which medication option to choose. If a subsequent determination by the insurance is required, the delayed decision should be placed in a queue that can subsequently be completed to optimize compliance, efficiency, and outcome.

4.B.19. Meeting medical necessity documentation for procedures, medications, transportation, convalescence, or work restriction

Providers are in some cases required to provide documentation to meet legal requirements for documentation. Examples include documentation for procedures, medications, transportation, convalescence, or work or driving restrictions. Providing support would reduce the complexity of ensuring that requirements are met efficiently and accurately and help optimize outcomes and compliance.

4.B.20. Meeting informed consent requirements with procedure specific details

Providers are required to obtain informed consent from patients for medical procedures. Having the ability for patients and caregivers to obtain this information prior to the visit would improve the ability for them to make an informed decision and to have an efficient visit and help optimize outcomes and compliance.

4.B.21. A holistic approach to the goal of optimizing patient compliance to scheduled follow-ups and needed medical regimen

Providing high quality care to patients is increasingly being defined to include applying evidence-based strategies to improve patient compliance to a treatment plan. Data in the electronic health record can help to inform a "learning health system" about what approaches to achieving patient compliance are best suited to patient cohorts based on an individual patient's historical compliance as well as generalized ethnic and other compliance information such as family caregivers' preferences.

4.B.22. Integrating surgical notes into the EHR

Surgical minor procedures in a clinic setting as well as more involved procedures in an ambulatory surgery center or a hospital need to be directly integrated into the patient's medical record in order to provide appropriate follow-up care.

4.B.23. Identifying, retrieving and displaying prior similar specialty prior notes

Providers should be able to easily identify and retrieve prior notes within their own specialty over time. This includes subspecialty specific queues. For instance, having any subspecialty notes buried in Ophthalmology, notes can be very laborious to retrieve if each note must be opened. In particular, having the ability to group notes by specific provider or provider type would be useful; examples of specialists in Ophthalmology include optometry, comprehensive Ophthalmology, pediatric Ophthalmology, vitreoretinal surgeon, glaucoma, cornea, and uveitis specialists. Notes would ideally be viewed separately as a past ocular history rather Bethan needing to be extracted from a complete past medical history.

4.B.24. Drawing templates with annotations, icons, and auto-generated text

There is a wide variety of needs in Ophthalmology regarding requiring drawing templates. In some settings, annotation over images would suffice, however in other settings and before images are taken, drawings are frequently used and having icon to text generation including type of pathology and location would be helpful and efficient. Examples include color coding of lesions, such as having hard exudates be yellow, veins be blue, and arteries be red.

4.B.25. Comparing images over time within the EHR

In Ophthalmology, comparing images previously taken compared to the current visit is centrally important in detecting clinical findings. Graphing images retrieved from integrated devices might be more likely to fail than drawn directly from the EHR data repository. Examples include OCT images, visual field data, corneal topography, and axial length measurement.

4.B.26. Orders including requiring unique data fields for the specialty area

In Ophthalmology, there can be unique data fields for orders. For example, eye drop medications need to specify which eye (right eye, left eye, or both eyes) and the number of drops (which frequently differ for one eye as compared to the other in certain diseases such as uveitis). For uveitis, there is often a long tapering regimen over weeks of less frequent administration of eye drops per day.

4.B.27. Supporting sub-specialty-specific classification of patients based upon examination findings

In Ophthalmology, patients are often classified at the sub-specialty level based upon findings from eye examination. These classifications could be supported by targeted software classification based upon easy-to-enter examination findings. For example, there could be tabs for subspecialty care clinics; examples include Age-related Macular Degeneration (AMD), diabetic retina, glaucoma, etc. For example, a diabetic retina clinic could have a list of retinal features which can be checked off as the patient is examined, and the software generates a classification based upon the selected lesions. If only Microaneysms are selected, the classification is mild Nonproliferative Diabetic Retinopathy (NPDR). If hard exudates are selected as well, then the classification is maculopathy. When certain lesions are selected, then additional prompts appear to look for additional indicators, such as new vessels in diabetic retinopathy. In general, using targeted displays with fewer "clicks" required to enter structured data by minimizing navigation across screens and reducing dialog boxes would be useful for all providers in all specialty care areas. On the other hand, flexibility is needed to navigate to other templates or areas of the EHR when new findings are identified.

4.C. Discharge

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs during the period at the conclusion of the visit (discharge). Opportunities for providing support during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

4.C.1. Informing patients about whether medications need to be obtained immediately following the visit

For some care situations, obtaining medications needs to be done immediately following the visit rather than the typical situation of within a day or two following the visit. Taking advantage of knowledge of the diagnosis and medication to highlight this need for patients would be useful.
Supporting informing patients of this information, such as by integration into a printout received at the conclusion of the session, would be valuable.

4.C.2. Informing patients what to watch for and who to contact if particular events happen

After the visit, patients will occasionally need to contact a healthcare provider in the event that something unexpected or undesirable occurs. An example is explaining the symptoms of retinal detachment for patients with posterior vitreous detachment. Supporting informing patients of this information, such as by integration into a printout received at the conclusion of the session, would be valuable.

4.C.3. Optional redaction of particularly sensitive patient information from after-visit summaries

In all care settings, patient information has the potential to be highly sensitive, including mental health diagnoses, infectious diseases, obesity or drug use, genetic information, and information which could impact a professional or personal reputation. Given that providing this summary is a requirement for Medicare reimbursement, having an option to print a redacted After Visit Summary at the completion of the visit would be helpful. A related issue is that patients may not wish to give personally identifiable information associated with their patient data. It would be extremely useful for the EHR to permit anonymization of patient data per patient's wishes.

4.C.4. Supporting optimizing patient compliance

Patients may need to be on a certain medication regimen or have certain procedures or tests performed. There should be queue management including automated contacting of the patient when there is no evidence that medications have been filled or tests have been performed. If critical care steps haven't occurred, as evidenced by lack of receipt of evidence from the pharmacy that a medication for a particular patient was dispensed or from imaging centers that a particular imaging test hasn't been performed, the lack of compliance can be escalated as warranted to automatically contact the patient and subsequently involve support staff or provider. The queue should be alterable to not overwhelm the user with queue fatigue and should be alterable to specific patient's needs, reliability of receipt of external data, and provider workflow.

D. Documentation

Documentation of a visit is not conducted in any particular step in the workflow. Some specialists begin documentation prior to the visit and make all orders and complete all documentation while with the patient. Some complete documentation in-between patients or during breaks. Some complete documentation the night after a visit was completed. Documentation elements include:

- Relevant history, physical, assessment, plan;
- Detailed descriptions to 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.

During the discussions with the SMEs, several suggested the addition of new features or increased flexibility for the workflow to better meet their needs. Additional opportunities were identified for useful features, including 1) automatic generation of clinic letters, 2) the capability to produce audits on patient outcomes or a summary of procedures and complications, and 3) retrospective analysis of patient data for research purposes (e.g., complications for patients getting cataract surgery). Opportunities for providing support during a typical return visit via the EHR for cognitively challenging tasks suggested by the SMEs are detailed below.

4.D.1. Correcting auto-generated information which is inaccurate

All of the healthcare providers had experiences with inaccurate information which was auto-generated from devices or software packages for a variety of reasons. Unsurprising sources of inaccuracies included sensor failures, missing data, and "wrong patient" data. Some of the sources of inaccuracies were unexpected, including poorly designed data tables where deleted records resulted in diagnoses/problems migrating from the deleted patient to the next patient in the data table, additions and customizations to data tables lost during software upgrade installations, inaccurate demographic data entered by clerks, data from test patients included in reports (e.g., address as 321 Blastoff Avenue), when software upgrades return previously addressed "bugs" such as incorrect placement of the right and left eye or cause data loss when permissions are incorrectly set for roles, dates defined as when data were entered rather than when an eye examination was conducted, lost data when using auto-build documentation features such as structured text and smart phrases, unusual uses of dropdown options for purposes other than intended by system designers (e.g., "Source radio/TV" as an option for a referring physician to track where patients had heard about the clinic), and interface interactions unexpectedly deleting data (e.g., double-clicking deletes image data without warning or the ability to recover). Not having the ability to correct inaccurate information is potentially dangerous when providing care. Workarounds such as creating an addendum to a note stating that a patient has an inaccurate diagnosis listed are likely not effective, and certainly are suboptimal. The auto-generated notes can sometimes only be viewed when a legal discovery request occurs sometimes providing surprising auto-generated information that is incorrect. Viewing all entered

and auto-generated data associated with a patient visit should occur prior to having the data enter the medical record.

4.D.2. Drafting documentation and encounter forms which are tailored to diagnostic information

In Ophthalmology, there are predictable patterns of care which can form the basis for draft encounter forms and other documentation facilitation. In addition, there are indicators that could be taken advantage of relating to the certainty that plans will go as expected. For example, annual eye screenings follow a predictable routine unless there are chronic problems such as, glaucoma, or diabetes, or past abnormal findings from eye examinations. There will also be the need to document in a different template because of new findings.

4.D.3. Reducing logins and sign-offs for multiple software packages and devices used to accomplish related functions

In specialty care, niche software and devices are frequently employed that are not used or available in inclusive EHRs. Having support for a single login process, reducing challenge questions and other keystrokes during logins, and reducing additional logins following automatic sign-offs would be beneficial. There are some unique elements to these needs for these areas in Ophthalmology, including signing into a different workstation required locating and signing off of another workstation with an active login. Being routinely required to sign off when leaving a patient room is undesirable and inefficient. Also, imaging software repositories ideally should be opened within one EMR to avoid errors or time inefficiencies associated with having to locate the correct patient within the associated applications. Ophthalmology providers in certain settings also describe the need to login and locate a specific patient in several separate applications simultaneously including laboratory, radiologic imaging, ocular imaging, outpatient scheduling, and surgical scheduling. In order to accomplish this goal, HIPAA privacy and security rules need to be followed in order to protect Personal Health Information (PHI) data and mitigate the risks of identity theft.

4.D.4. Annotating documentation by patients and caregivers in a progress note

More patients are expected in the future to take advantage of the so-called 'blue button' opportunity to view their progress note documentation. The demand will likely increase to correct misinformation or otherwise annotate the note. Because the patient is not a healthcare professional at the organization, it is likely inappropriate to use the workflow for corrections to the health record from professionals. Therefore, this information should be displayed in a different fashion, such as a "comment" in a margin or upon roll-over of the relevant information along with information about who entered the comment and when. One provider stated that having physicians engage in discussions about aspects of the chart, including requests from patients to explain portions of a note to them, would be an undesirable outcome due to the additional workload burden. Therefore, the design would likely need to restrict "back and forth" communications between physicians and patients about annotations and progress note information.

4.D.5. Having additional protections on personal health information

Although current examples of issues with personal health information being disseminated beyond the wishes of patients and caregivers were not commonly observed, several of the providers expressed concerns about the potential for this to occur and described individual anecdotes as "proof of concept" that issues could arise. Data repositories are being generated with access being provided to non-traditional users, such as schools in order to verify immunizations. In general, it is anticipated that a subset of patients will feel strongly about the desire to protect a particular data element from use in population health research or other population-based initiatives (e.g., marketing studies). Providing electronic support for "opting in or out" along the lines of organ donor programs would be an interesting area for consideration in the next generation of EHRs. Possible areas might include "Do Not Resuscitate" advance directives or not allowing blood transfusions for religious reasons (e.g., Jehovah's witness patients).

Accomplishing this objective will likely require negotiations between stakeholder groups with differing, and potentially conflicting, perspectives in this relatively uncharted territory.

4.D.6. Advanced features for image management, including extraction of quantitative data and images without being dependent on interfaces with other applications

Advanced features and technological innovations in working with images would be beneficial for Ophthalmology. In particular, extracting quantitative data from images would be useful. There are third party niche applications providing support in this area, but the interfaces can be expensive or unreliable for integration.

5 Targeted Recommendations for EHR Developers for Improving Workflow in Obstetrics and Gynecology and Ophthalmology

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 specialty care outpatient centers for Obstetrics and Gynecology and for Ophthalmology. In specialty care areas where there are specialized support staff for clinical purposes, there can be fewer ancillary support that facilitate meeting documentation, billing, and legal requirement. Therefore, there is an opportunity for the EHR to optimize the provider's goal of having the patient receive the needed care by helping the provider meet efficiently and accurately complex documentation, insurance, and regulatory requirements. Finally, a distinguishing feature of specialty care areas is the diverse set of niche devices and software packages which need to integrate with the EHR for optimal workflow and to reduce the cognitive load for a physician wanting a summary "gist" of a patient immediately prior to a patient encounter. Therefore, the EHR needs to integrate and group data from diverse sources and in diverse formats. Following are targeted recommendations which distill the lessons learned from the insights detailed in Section 2.

For EHR developers interested in increasing EHR adoption in outpatient clinics primarily providing obstetrical care, we recommend the following to improve EHR-related workflow during the patient visit:

- Displaying summary information for an individual patient in the format recommended by the American College of Obstetrics and Gynecology-, which matches how specialist physicians were trained to recognize patterns for ante-partum care
- Supporting integrating information from specialized devices, software, data repositories
- Supporting graphing of viewing formatted data (tables) over time to identify patterns and trends including extracting data from devices
- Providing a draft order set to modify during the visit which is tailored to diagnostic information and number of weeks pregnant
- Supporting optional redaction of particularly sensitive patient information from after-visit summaries
- Reducing logins and sign-offs for multiple software packages and devices used to accomplish related functions

For EHR developers interested in increasing EHR adoption in outpatient clinics primarily providing Gynecology care, we recommend the following to improve EHR-related workflow during the patient visit:

- Distinguishing between patients with a very high likelihood of getting a particular treatment from patients who are less likely to get the treatment
- Alerting with the information about patients that informs how to conduct a patient visit
- Providing a draft order that can be modified during the visit which is tailored to diagnostic and demographic information
- Supporting hands-free interaction with the EHR during procedures
- Supporting optional redaction of particularly sensitive patient information from after-visit summaries

For EHR developers interested in increasing EHR adoption in outpatient clinics providing ophthalmology care, we recommend supporting the following to improve EHR-related workflow during the patient visit:

- Orders for the specialty area, including requiring unique data fields
- Verifying that insurance requirements are met during the scheduling process

- Flexible real-time assignments of different staff to tasks across multiple patients simultaneously Cosigning of ancillary support notes and findings
- Integrating information from specialized devices, software, data repositories
- Grouping conceptually related items with different formats (e.g., CIF, image, scanned image, fax, PDF, searchable text, structured data), particularly redundant data
- Annotations by patients and caregivers to documentation in a progress note
- Advanced features for image management, including extraction of quantitative data and images without being dependent on interfaces with other applications
- Additional protections on personal health information
- Distinguishing between patients with a very high likelihood of getting a particular treatment from patients who are less likely to get the treatment

For two specialty care areas, we identified similar "pain points" which could be considered in efforts targeted at other specialty care areas with unique requirements. These issues span many areas in the design and implementation of EHRs, including:

- Adding data fields required for specialty care areas, such as the number of drops and which eye for application for medications
- Following labeling conventions for specialty care areas, such as the definition of right and left eyes and standardized color coding for types of eye lesions
- Reducing navigation steps to access and update the relatively small subset of historical information, medications, and laboratory and procedure results needed for the specialist; this includes having quick access to a tailored summary, the tasks to be performed during the visits for testing and treatments, and what sign-offs are required for actions such as labs; not having to use multiple software packages with overlapping functionality in order to view diagnostic testing results would also reduce navigation costs
- Supporting patient scheduling to meet target windows for optimal care, identify patients who can be safely deferred, accommodate predictable needs for additional time, identify patients who have not yet scheduled critical visits, and incorporate constraints from insurance requirements for reimbursable tests in a particular visit
- Reducing the relative benefits of using workarounds compared to the intended design use of features which negatively impact the usability of the interface and accuracy of documented information; specifically, anticipating actions to make them done more efficiently during the visit to increase the ability to communicate with empathetic eye contact with the patient and reducing the time to document progress notes and adding information to displays and templates which are displayed in problem lists (but are not problems)
- Supporting voice activation for documentation during "hands-on" examinations with patients while holding specialized equipment, particularly when reduced physical interactions with keyboards and screens to reduce infection is important
- Integrating information from devices unique to the specialty care areas; of particular interest is increasing the efficiency of logins and signoffs, maintaining the quality of large imaging and video files when accessed via the EHR, and supporting documentation of the review of data from devices without requiring redundant or "out of sequence" documentation
- Integrating information from pharmacies directly into the EHR
- Supporting communications with patients, including reminders and suggestions for correcting or augmenting documented information; balancing additional burdens on the physician and providing access and the ability to correct and comment on information is important; for After Visit Summaries, allowing patients to redact sensitive data would be beneficial, particularly for Obstetrics care

- Considering opportunities for use of the EHR data across patient cohorts for research and quality improvement initiatives and for avoiding undesirable uses of the data such as for marketing purposes.

Overall, our recommendations provide a first step in applying a traditional human factors modeling technique to two diverse specialty care areas in order to suggest directions to pursue to further advance the widespread implementation of EHRs which are tailored to local specialty care needs. Our findings suggest that, even within these two areas, there is high variability within the specialty area based upon the type of patient condition, patient demographic variables, the health condition, the uniqueness of the treatment plan, the organizational support, the clinic staffing, and individual patient factors that influence the risk of missing appointments or failing to comply with treatment plans.

Some of the recommendations relate directly to improving patient safety as well as workflow. For example, patients are at risk of morbidity, and possibly mortality in some situations, if they do not receive treatments within evidence-based time intervals, such as providing integrated access to data from specialized devices in an efficient and usable manner, having orders include unique data fields for the specialty area such as drops in the right or left eye, and having visual representations of data match specialty-specific norms, such as having the right eye be defined from the perspective of the patient.

As electronic health records are conceptualized more uniquely in order to better fit the workflow patterns of a particular niche, it will likely be more difficult to have an inflexible standardized approach to implementation, maintenance, and information sharing. Debates on the relative advantages and disadvantages of niche "best of breed" EHRs as compared to "one size fits all" EHR designs are not new. On the other hand, some of the opportunities identified for specialty care areas may be viewed as useful or meet a similar need in other areas where it has not been highlighted to be a priority need. In addition, it may be possible to have a standardized approach to the format, structure, and approaches to retrieving data without having a standardized approach to workflow design and visualizations which support that workflow directly, and thus likely improve patient outcomes.

6 Conclusion

In response to workflow integration challenges with ambulatory physicians using EHRs, we have employed a standard human factors method in order to identify insights for EHR developers and ambulatory care providers in Obstetrics and Gynecology and in Ophthalmology. The method illustrated in this document is process maps 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. For two specialty care areas, we identified similar "pain points" which could be considered in efforts targeted at other specialty care areas with unique requirements, such as dental care, occupational therapy, and physical therapy. We have identified a wide variety of potential opportunities to improve workflow with EHRs from a physician perspective. In order to increase the ease of implementing our insights, we provide a set of targeted recommendations for EHR developers interested in better serving the unique needs of these users.

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