Mature EMR use by primary care physicians in Ontario: A multi-methods study

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Dissertation Abstract

There is a need globally to strengthen primary health care to address population health issues, such as the increased prevalence of chronic diseases. While there is evidence supporting the benefit of using electronic medical records (EMRs) in chronic disease prevention and management (CDPM), use of advanced EMR features by health care professionals is limited. As such, little is known about the barriers and facilitating factors that influence the mature use of advanced EMR features by primary care physicians (PCPs). Furthermore, there is a gap in our knowledge of how advanced EMR features are being used to achieve their intended benefits. This study applies a multi-method approach to explore the mature use of advanced EMR features used by PCPs in the province of Ontario, Canada.

Methods:

This study involved three phases:

1) A systematic review to identify factors influencing PCPs' mature use of EMR features.
2) A qualitative study to explore PCPs' experiences with the use of advanced EMR features to support CDPM.
3) A lean process mapping study to understand how PCPs integrate advanced EMR features into their laboratory results management workflow and a recommendation for a future-state process to enhance their current-state processes of laboratory results management.

Results:

1) Of the 1893 studies identified, 14 were eligible. Reported factors that influenced PCPs' mature use of EMRs fell into one of the following five categories: technology, people, organization, resources, and policy. Common barriers to the use of advanced EMR features were concerns about the functionality of the features, limited physician availability to learn more EMR features, poor vendor training, and lack of physician readiness. Common facilitating factors were physician's motivation, user satisfaction, coaching and peer mentoring, physicians' perceptions towards the benefits of using advanced EMR features with respect to the quality of care, adequate technical support and training, and practices that were in an integrated delivery system.
2) Nine face-to-face interviews with PCPs revealed key factors that impacted their use of advanced EMR features: performance of EMR features, information quality of EMR features, their level of training and technical support, user satisfaction, provider's productivity, PCPs' characteristics, cost benefits of EMR features, EMR systems infrastructure, funding, and government leadership.
3) Observations of nine Ontario PCPs led to six improvement strategies to enhance their current-state processes of laboratory results management using advanced EMR features: (1) encourage physicians to analyze patients' laboratory results prior to meeting them, (2)

ensure that laboratory results are available on the patient's chart prior to the patient's appointment, (3) provide on-going training for physicians and support staff, (4) use a checklist or a software tool to reduce the mismatch rate of laboratory results to a patient's chart, (5) maintain an adequate physician-to-staff ratio to minimize backlog, and (6) provide a mechanism (e.g., use of the EMR reminder feature or a software tool) to track patients' laboratory results in their EMR.

Conclusion:

The mature use of advanced EMR features by PCPs was influenced by several factors. The findings from this study can inform vendors (e.g., IndiviCare, Telus), policymakers (e.g., The College of Physicians and Surgeons of Ontario), federal and provincial organizations responsible to drive EMR maturity (e.g., Canada Health Infoway, OntarioMD), and health care professionals in devising approaches to overcome barriers to and support mature use of EMR features for CDPM.

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List of Abbreviations

AFHTO	Association of Family Health Teams of Ontario
AMSTAR	A MeaSurement Tool to Assess Review
ARRA	American Recovery and Reinvestment Act
QIDS	Quality Improvement Decision Support
CAF	Clinical Adoption Framework
CCM	Comprehensive Care Model

CHC	Community Health Center
CDPM	Chronic Disease Prevention and Management
eHealth	Electronic Health
EHRs	Electronic Health Records
EMRs	Electronic Medical Records
FFS	Fee For Service
FHG	Family Health Group
FHN	Family Health Network
FHO	Family Health Organization
FHT	Family Health Team
GRADE-CERQual	Confidence in the Evidence from Reviews of Qualitative Research
HIS	Health Information System
HITECH	Health Information Technology for Economic and Clinical Health
MeSH	Medical Subject Headings
MoHLTC	Ministry of Health and Long-Term Care

MU	Meaningful Use
PCPs	Primary Care Physicians
PHO MetaQAT	Public Health Ontario Meta-tool for the Quality appraisal of public health evidence
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses

Chapter One. Introduction

This chapter describes the study's statement of problem, objectives, and the format of this dissertation.

1.1 Statement of Problem

The governance, organization, and delivery of Canada's healthcare services are decentralized between the federal, provincial and territorial governments. The federal government is responsible for certain aspects of health and pharmaceutical regulation and safety, as well as the financing and administration of health benefits and services for specific populations (Marchildon, 2013). The provincial and territorial governments are primarily responsible for a broad range of social policy programmes and services including the bulk of publicly financed and administered health care services (Marchildon, 2013).

Primary care reform in high-income countries such as Canada progressively aims to improve the quality of health care services, improve the health of the population, and address increasing health care costs (Schoen et al., 2012). To achieve the above objective, Canadian policymakers recommend that electronic medical records (EMRs), a health information system (HIS), be used to facilitate early prevention of chronic diseases, clinicians working together as a group, better communication among care team members and between providers and patients, the mitigation of inefficiencies in clinicians' workflow, and reduce the number of duplicate tests and adverse drug events (Schoen et al., 2012; Zelmer & Hagens, 2014). However, Canada does not have a national health informatics infrastructure and that is largely due to how the Canadian

health care system assigns responsibility to provinces and territories for the funding and delivery of most healthcare services. As a result, provinces and territories are responsible for developing, implementing, and financing their own EMR system (Auditor General of Canada, 2010).

EMRs are one of the many electronic health initiatives (i.e., eHealth) aimed at supporting Canada's primary care reform (Government of Canada, 2015). Between 2001 and 2010, Health Canada invested 2.1 billion dollars in eHealth initiatives that included increasing the number of community-based clinicians adopting and using EMR systems (Government of Canada, 2015). In 2017, Health Canada allocated $300 million over five years to support the continued adoption and use of EMRs, in addition to other priorities in digital health (Government of Canada, 2015).

According to the latest National Physician Survey (2014a), family physicians reported clinical benefits of EMRs such as remote access to patient charts, improved availability of lab results, alerts for potential medication errors, and reminders for preventive care. As well, 65% of respondents reported that patient care improved after they implemented EMRs (NPS, 2014a). Furthermore, a study found that use of advanced EMR features improves health outcomes and patient safety through preventive care and chronic disease management (Canada Health Infoway (Infoway), 2013a). Moreover, the 2018 Canadian Physician Survey (Infoway, 2018a) reported that high physician satisfaction with EMRs and access to regional, provincial or territorial health information systems has a lot to do with the use of multiple EMR functionalities to support patient care (Infoway, 2018a).

The use of EMRs across Canada has increased since they were first introduced. In 2014, 77% of PCPs were using EMRs (NPS, 2014a), as opposed to 24% in 2007 (NPS, 2007). Despite the increase in EMR use, not all practices use them to their full potential. An international survey conducted in 2012 showed that Canadian practices with five or more full-time equivalent physicians were significantly more likely to use EMRs and use at least two EMR features than practices with fewer than two full-time physicians (Schoen et al., 2012). Furthermore, the 2018 Canadian Physician Survey (Infoway, 2018a) found that 31% of PCPs that participated in the survey (N=799) used 6 to 9 EMR functionalities to support patient care.

Family physicians that participated in the latest National Physician Survey reported having experienced barriers while accessing EMRs. About half (52%) reported technical glitches or reliability issues, 44% reported compatibility problems with other electronic systems, and 22% reported firewalls or security issues (NPS, 2014a). As well, in the 2018 Canadian Physician Survey (Infoway, 2018a) physicians that participated in the survey reported that a critically important facilitator to help advance their provision of virtual and e-services are guidelines to ensure privacy and security, improved technology and support services provided by medical associations or government bodies (Infoway, 2018a). Thus, achieving mature use of EMR features is currently a challenge, and there is a gap in our understanding of how EMR features are being used and the factors impacting mature EMR use to achieve their intended benefits.

1.2 Study Objectives

The goal of this study is to promote the delivery of primary health care, specifically for Chronic Disease Prevention and Management (CDPM). A further goal of this study is to develop evidence-based recommendations to assist key decision-makers (e.g., practice managers, providers, vendors, policy makers) determine which strategies support the mature use of advanced EMR features by PCPs in order to support CDPM. Beyond that, the study strives to ascertain the barriers and facilitating factors that influence the mature use of EMR features in the support of primary care delivery. This, in turn, can provide future research direction regarding support for improving the mature use of EMRs by PCPs.

A multi-method study was used that focused on the following objectives. Independent conclusions are derived from each objective:

1. To conduct a systematic review to determine the factors influencing PCPs' mature use of EMR features.
2. To conduct semi-structured interviews to identify the barriers and facilitating factors that PCPs in Ontario experience when using advanced EMR features to support CDPM.
3. To conduct an observational study to explore how EMRs and their features are integrated into Ontario PCPs' workflow processes in support of CDPM, specifically laboratory results management.

1.3 Implication for Health Systems

The goal of this thesis is to contribute to the field of health systems. Moreover, this thesis can contribute to other aspects of Canada's health system since a resilient and high functioning health system needs other aspects of healthcare such as both primary care and population health. Population health is an important field and this thesis plays a role in population health by promoting the delivery of care for patients with chronic diseases, living in Ontario. Furthermore, secondary care can also be influenced by this thesis since the support of the mature use of EMRs by PCPs encourages PCPs to use advanced EMR features that can allow efficient exchange of EMR documents (e.g., referrals, medical reports) and communication between PCPs and specialists. In addition, the thesis can contribute to tertiary care by motivating PCPs to use advanced EMR features that can allow physicians to receive hospital reports (e.g., discharge summaries). This way PCPs are still involved and can continue managing their patient while the patient is in tertiary care. As well, by having PCP involved may enhance long-term self-management by the patient, which in turn support population health.

The desired outcome of this dissertation is to establish evidence-based recommendations that will assist key decision-makers (e.g., managers of primary care practices, PCPs, EMR vendors, and organizations responsible to drive EMR maturity) identify the barriers to and facilitating factors for mature use of EMR features in support of CDPM, and to make decisions that will improve the use of EMR features that support CDPM workflow processes.

1.4 Dissertation Format

The format of this dissertation is manuscript-based. (See Table 1.1 for a summary of the format.) Chapter 1 discusses the study's research problem, objectives, and dissertation format. Chapter 2 is a literature review that looks at core EMR features used in CDPM, the establishment of EMRs in Canada, and family practice models used in Ontario. The concept of mature EMR use is also discussed in Chapter 2. The methodologies used in this dissertation are described in Chapter 3. Chapter 4 is a systematic review that aims to determine the factors influencing the mature use of EMR features by PCPs. Chapter 5 is a qualitative study that explores Ontario PCPs' experiences of using EMRs and their features to deliver primary care. Chapter 6 is an observational study that uses process maps to uncover how EMRs and their features are integrated in the workflow processes of Ontario PCPs. Chapter 7 provides a discussion of the dissertation findings. Chapter 8 concludes this dissertation by identifying the contributions of each author of this dissertation.

Table 1. 1 Summary of dissertation format

Chapter #	Chapter Title	Objective(s)	Methods	Manuscript Format
1	Introduction	Describe the research problem and objectives; explain the dissertation format	N/A	American Psychological Association
2	Literature Review	Explore the type of EMR features used for CDPM, the concept of mature EMR use, and HIS adoption and maturity models	Literature review	American Psychological Association
3	Methodology	Discuss dissertation methodologies in detail	N/A	American Psychological Association
4	Factors Affecting the Mature Use of EMRs by PCPs: A Systematic Review	Determine factors influencing the mature use of EMR features by PCPs	Systematic review	BMC Medical Informatics and Decision Making
5	Primary Care Physicians' Experience Using Advanced EMR Features to Support Chronic Disease Prevention and Management: Qualitative Study	Explore PCPs' experiences of using EMRs and their features to deliver primary care	Direct content analysis guided by the Clinical Adoption Framework	Journal of Medical Internet Research Medical Informatics

6	Process Improvement for the Management of Laboratory Results Using EMRs in a Primary Care Setting	Uncover how EMRs and their features are integrated into the work processes of Ontario PCPs	Observational study using process maps	International Journal of Medical Informatics
7	Discussion	Provide a discussion of the dissertation findings	Descriptive Synthesis	American Psychological Association
8	Contributions	Describe the roles of members involved in dissertation	N/A	American Psychological Association

Chapter Two. Literature Review

This literature review begins with a discussion of the background of the establishment of EMRs in Canada. Section 2.2 presents the type of primary care models used in practices in Ontario. Section 2.3 provides an overview of the core EMR features used for CDPM. Section 2.4 reviews the current state of EMR use for CDPM. Section 2.5 discusses the concepts of meaningful and mature use of EMRs. Section 2.6 provides an overview of HIS adoption and maturity models. Finally, the chapter concludes with a summary of the literature.

2.1 Establishment of EMRs in Canada

A pan-Canadian policy undertaken in the mid-2000s focused on the need to reform primary health care by emphasizing the adoption of EMRs (Zelmer & Hagens, 2014). In 2001, Canada Health Infoway (Infoway) was formed, a not-for-profit corporation funded by the federal government. Infoway's mandate is to accelerate the development, adoption, and effective use of EMRs (Zelmer & Hagens, 2014). In 2010, the federal government invested in the establishment of EMRs in primary care setting with the intention to improve access to care, quality of health care services, and the productivity of the health system, and to reduce health care costs (Zelmer & Hagens, 2014). To this end, the federal government funded Infoway to increase the number of primary care clinicians that use EMR systems (Zelmer & Hagens, 2014). Infoway established a program to support jurisdictions, health care providers, and vendors in furthering the implementation and increasing the use of EMRs. One of the aims of this program was to certify

EMR systems on the basis of privacy, security, and interoperability criteria, such that EMR products met jurisdictional and national interoperability specifications (e.g., to connect EMRs to provincial repositories of lab or prescription drug information) (Zelmer & Hagens, 2014). In Ontario, OntarioMD, a cooperation owned by the Ontario Medical Association, is held responsible for certifying EMRs in Ontario and ensuring that they meet the required standards (OntarioMD, 2011).

In order to increase EMR adoption in Ontario, the Government of Ontario offers financial support to primary care practices. OntarioMD is responsible for administering this subsidy to physicians. Primary care practices have to meet certain criteria in order to be eligible to receive a subsidy. Only certain types of family practice models are funded. However, in 2015, EMR funding programs from OntarioMD closed since the rate of EMR adoption met provincial goals. The next section provides an overview of the type of primary care models used in Ontario.

2.2 Family Practice Models

In Ontario, three types of models of primary care practices serve patients: solo-setting, group-based, and team-based. Solo practices are independent practices with few support staff, and physicians receive payment for each individual service they provide to their patients (e.g., physical exam, immunization, prescription) (Glazier, Zagorski, & Rayner, 2012). This is known as fee-for-service (FFS) (Glazier, Zagorski, & Rayner, 2012). Primary health care in Canada has traditionally been funded through FFS payments. FFS encourages physicians to provide services

that may not be necessary and to see a high volume of patients (Glazier, Zagorski, & Rayner, 2012). The Comprehensive Care Model (CCM) is similar to the FFS model. In this model, physicians are compensated primarily through FFS. However, they are also eligible for specific bonuses based on patient enrolment (Ontario, 2020).

Group-based models of care usually have three or more physicians working together, and patients are enrolled under the care of one physician (Glazier, Zagorski, & Rayner, 2012). In these models, physicians provide some after-hours care on evenings and weekends. Family health groups (FHGs), family health networks (FHNs), and family health organizations (FHOs) are group-based models of care (Ontario, 2020). In the FHG model, physicians are compensated primarily through FFS but are also eligible for specific bonuses based on patient enrolment (Ontario, 2020).

An alternative to the FFS payment is a capitation system in which physicians are paid a fixed fee to provide care to a defined number of patients under their care (Glazier, Zagorski, & Rayner, 2012). Typically, capitation systems do not pay equally for every patient but take into account the patient's health needs (Glazier, Zagorski, & Rayner, 2012). This way, physicians are encouraged to keep patients healthy and encourage prevention because they do not receive additional income when patients are sicker (Glazier, Zagorski, & Rayner, 2012). A disadvantage of this system is that it offers too little incentive to provide services and physicians may limit their hours of practice (Glazier, Zagorski, & Rayner, 2012).

As an alternative, a blended capitation payment was developed. FHO and FHN models are compensated through such payments. In this system, physicians have a roster of registered patients and receive a base payment for each patient enrolled; payments are adjusted for age and sex. Physicians also receive FFS payments for treating non-enrolled patients and receive incentives and bonuses for selected evidence-based health care services (e.g., prevention, treatment, and management of chronic diseases and health promotion) (Glazier, Zagorski, & Rayner, 2012).

Family health teams (FHT) uses a team-based model. (Glazier, Zagorski, & Rayner, 2012). PCPs that work in a FHT are not paid by the FHT, but rather are members of an FHO that resides within the FHT, as there is no money flowing from the FHT to the physician for clinical services. Thus, while PCPs in a FHT are participants in a sophisticated team-based care model, their payment methodology is exactly the same as that of the FHO physicians in other group-based models. In the FHT model, physicians work as part of an interdisciplinary team with allied health professionals (e.g., pharmacists, dieticians, nursing, and kinesiologists) to provide comprehensive care to patients (Glazier, Zagorski, & Rayner, 2012). Community health centres (CHCs) are another version of the team-based model. However, the inter-professional team of physicians and other allied health professionals are salaried. CHCs typically serve high needs populations that face difficulty accessing health care services (Glazier, Zagorski, & Rayner, 2012).

The Government of Ontario began an initiative called the Quality Improvement Decision Support (QIDS) program to assist FHTs advance their performance measures and quality improvement with the support of QIDS specialists. The program is operated by the Association of Family Health Teams of Ontario (AFHTO) on behalf of the provincial government (AFHTO, 2015). In 2015, over 30 QIDS specialists were shared among FHTs across the province to assist them in accessing and using data better from their EMR system. QIDS specialists extract health information from EMR systems to facilitate quality improvement for the FHTs (AFHTO, 2015). For example, they may perform data analysis on EMRs or provide support to management to assist in decision making for quality improvement purposes, assist in the standardization of information entered in EMRs (such as common language, terms, nomenclature), or develop queries to support clinical teams' outcome improvements (AFHTO, 2014).

2.3 EMR Features Used for CDPM

In Canada, chronic diseases are the leading cause of death and hospitalization for Canadians aged 35 and older (Public Health Agency of Canada, 2005). Sixty percent of Canadians aged 20 years or older have been diagnosed with a chronic disease (Betancourt et al., 2014). Moreover, chronic diseases account for over 33% of direct health care costs in Canada (Ontario Ministry of Health & Long Term Care, 2007). In Ontario, the number of people with chronic diseases is expected to increase as Ontario's population continues to age (Public Health Ontario, 2012). Policymakers have recommended the use of EMRs to facilitate early prevention,

with the goal of addressing the increased prevalence of chronic diseases and reform primary care (Schoen et al., 2012).

"EMR" and "electronic health record (EHR)" as designations have been used interchangeably in studies (Boonstra & Broekhuis, 2010). Canada Health Infoway defines an EMR as a computer-based patient record specific to a single practice used by authorized clinicians and staff within one health care organization (Infoway, 2020a), while an electronic health record is an interoperable system that links clinics, hospitals, pharmacies, and other points of care and is used by authorized clinicians and staff in more than one health care organization (Infoway, 2020b). Due to the interchangeable use of "EMR" and "EHR" by some authors in American literature when referring to EMRs used in a primary care setting (Crosson, Ohman-Strickland, Cohen, Clark, & Crabtree, 2012), this dissertation follows Canada Health Infoway's definition of an EMR.

PCPs use EMRs in their practice to electronically maintain their patients' records: demographics, health and drug history, and diagnostic information such as laboratory results and diagnostic imaging results (Zelmer & Hagens, 2014). EMRs also offer multiple functions that have the potential to support CDPM, such as the creation of reminders, or alerts, for patient preventative and screening services (e.g., follow-up tests, procedures, patient education), immunization management, medication management, identification of patients who need additional care services, graphical illustration of the impact of treatment on laboratory tests or

other measures over time, and displaying, exporting, and printing data in different forms that can be used for further analysis (Vaghefi et al., 2016). EMRs also facilitate decision support for PCPs through the application and monitoring of evidence-based guidelines to improve health outcomes of patients with chronic diseases.

Common EMR features used for CDPM include electronic reminders, a recall system, medication reference, electronic prescribing, laboratory order entry and radiology order entry, and electronic communication tools (Hsiao, Marsteller, & Simon, 2014; Shaw, 2014).

The electronic reminder feature is used for preventive or follow-up care and automates reminders for specific tests based on recommended guidelines (e.g., vaccinations, mammograms, Pap tests, blood tests) (Hsiao, Marsteller, & Simon, 2014). Electronic reminders are typically triggered during patient encounter, informing the PCP to remind patients of systematic preventive care. A study by Hsiao and colleagues (2014) showed that visits to practices that used an EMR system that reminded PCPs about guideline-based interventions or screening tests resulted in better quality of care (e.g., lower odds of inappropriate urinalysis) compared to visits to practices where no reminders were given. Similarly, a study by Shaw (2014) showed that PCPs agreed that preventive care was improved when they were prompted by a reminder to schedule a specific test during the patient encounter.

The difference between a recall system and an electronic reminder is that reminders inform PCPs about recommended preventive activities for patients, whereas a recall system is an

EMR feature that generates a recall list report for preventive care activities or programs for patients enrolled with a physician. Typically, the recall feature provides a designated staff member with a recall list that can be used to call and remind patients about health visits, abnormal results, or the completion of a vaccination series.

During electronic prescribing, the medication reference feature alerts the physician of drug interactions and medication allergies (Shaw, 2014). More than 30% of physicians in Shaw's (2014) study stated that the quality of care improved when they used the EMR's functionality to track all the medications that a patient had taken and could quickly scan the patient's drug history, which in turn increased the efficiency of prescribing while reducing the risk of medication errors.

Electronic prescribing allows PCPs to electronically send prescriptions to the pharmacy, also known as e-prescribing (Shaw, 2014). In addition, Hsiao (2014) showed that visits to practices whose EMR systems included prescription order entry exhibited lower odds for a prescription of antibiotics for upper respiratory infection than visits to practices without reminders or prescription order entry.

Laboratory and radiology order entry allow PCPs to create requisitions within the EMR so that the appropriate investigations can be carried out (Shaw, 2014). In addition, several private laboratories were able to send the test results electronically to the EMR, at which point the health care provider received a notification that the patient's record had been updated (Shaw, 2014).

Hsiao (2014) determined that a review of lab results was associated with improved quality of care (e.g., lower odds of receiving inappropriate urinalysis). Shaw (2014) also observed that EMR features that had connectivity to private labs received results more quickly, and less time was spent on finding the results and matching them to the patient's chart.

A study initiated by the Institute of Medicine (Tang, 2003) found that effective communication between health care team members, other health care providers (e.g., pharmacies, laboratories), and patients was vital to the delivery of quality care. Furthermore, a lack of communication could lead to adverse events (Tang, 2003). Electronic communication tools, such as e-mail and instant messaging, have been efficient in assisting communication among both providers and patients, allowing for greater continuity of care and more timely interventions (Tang, 2003). Another form of electronic communication includes reviewing clinical notes, where messages are tied to a patient's chart.

According to Shaw (2014), advanced EMR features include automated reminders for tests and screening; decision support tools, such as a cardiovascular risk tool; a recall system to search for patients with a specific condition; customized templates, such as diabetic flow sheets; and a graph feature to view the trend of a patient's test results over time.

Although there are various EMR systems available in Ontario, the most common systems used at primary care clinics are PS Suite EMR produced by Telus Health (2019a), Nightingale On Demand, produced by Telus Health (2019b), IndiviCare produced by Indivica (2019) and

OSCAR produced by OSCAR EMR Inc. (2019). Advanced EMR features available in these systems include but are not limited to the following:

- Drug databases that provide dosing information, administration, and medication allergy alerts.
- Hospital Report Manager (OntarioMD, 2015), an Ontario provincial feature used to electronically integrate patient reports (e.g., medical records and diagnostic imaging reports) from hospitals and specialty clinics directly into a patient's chart.
- Ontario Laboratories Information System (OLIS) that automatically receives laboratory results from hospitals directly into the patient's chart (OntarioMD, 2019a).
- Electronic fax to electronically receive faxed documents into EMRs.

2.4 EMR Use for CDPM

Studies have shown that the main benefits of EMRs is providing preventive care and CDPM (Adaji, Schattner, & Jones, 2008; Baer, Cho, Walmer, Bain, & Bates, 2013; Black et al., 2011; Buntin, Burke, Hoaglin, & Blumenthal, 2011; Chaudhry et al., 2006; Delpierre et al., 2004; Infoway, 2013a; Jones et al., 2014; Lau et al., 2012; Lau, Kuziemsky, Price, & Gardner, 2010; Smith, Skow, Bodurtha, & Kinra, 2013; Vaghefi et al., 2016).

A 2015 international study conducted in 10 developed countries found variable and overall limited use of EMR features for CDPM (Commonwealth Fund, 2015). The study found that countries with the lowest rates of routine PCP use of computerized systems to send

reminders to patients when it was time for regular preventive or follow-up care were Norway (9%), Switzerland (14%), France (17%), Canada (18%), and the US (40%). The study also reported that about half (48%) of Canadian PCPs and about two-thirds (65%) of PCPs from the US were able to generate a list of patients who were due or overdue for tests or preventive care. Rates were even lower in Norway (16%), Switzerland (29%), Sweden (37%), and France (39%), while the UK, New Zealand, and the Netherlands were among the countries in the world with the highest EMR adoption rates (Commonwealth Fund, 2015). The study also reported that among the countries surveyed, the number of PCPs receiving reminders for guideline-based interventions and/or screening tests was relatively low: UK (77%), New Zealand (61%), Australia (56%), US (47%), Canada (26%), Germany (15%), Switzerland (9%), and Sweden (7%) (Commonwealth Fund, 2015).

Another study determined that Canadian PCPs have been using their EMRs as "electronic paper records" and only use the basic EMR features (Price et al., 2013). Likewise, other studies have reported that the majority of PCPs do not fully adopt advanced features even two years following implementation (Denomme et al., 2011; Loomis, Ries, Saywell, & Thakker, 2002; Price et al., 2013). This has led to personal dissatisfaction with their EMR system, time loss, and reduced productivity (Loomis et al., 2002), in addition to reduced quality and safety of patient care (Finney Rutten et al., 2014). The gaps found in the literature regarding the use of EMR features for CDPM suggest that internationally PCPs do not use EMRs to their full potential.

The next section describes the terminology used in the US and Canada to describe mature EMR use.

2.5 Concept of Maturity of EMR Use and Meaningful EMR Use

Meaningful use (MU) is a term that was developed in US legislation as part of the American Recovery and Reinvestment Act (ARRA) (Centers for Disease Control and Prevention, 2019). ARRA included the Health Information Technology for Economic and Clinical Health Act (HITECH), which proposed the MU of interoperable EHRs throughout the US health care delivery system (CDC, 2019). The HITECH Act defines MU as the use of certified EHR (e.g., electronic prescribing) technology in a meaningful manner; ensuring that certified EHR technology connects in a manner that provides the electronic exchange of health information to improve the quality of care (CDC, 2019). The objective of MU is to achieve better care and improved population health at a lower cost (Heisey-Grove, Danehy, Consolazio, Lynch, & Mostashari, 2014). As such, MU sets specific objectives that health care professionals and hospitals must meet in order to receive financial incentives for adopting and using certified EHRs (Rimmer, Hagens, Baldwin, & Anderson, 2014). MU objectives are broken down into three stages to enable health care professionals to progress and mature in their use of EHR features: (1) electronic capture of clinical data and sharing including giving patients electronic copies of health information, (2) advancing clinical processes and encouraging the use of

certified EHR technology, and (3) using certified EHR technology to improve health outcomes (CDC, 2019).

As the uptake of EMRs has increased in Canada, several provincial organizations responsible for the effective use of EMRs have shifted from support for implementation and adoption of EMR to the emphasis of mature use, or MU of EMR (Infoway, 2018b; OntarioMD, 2017; Rimmer et al., 2014). In Canada, MU has been used to refer to more mature use of EMRs, which includes richer functionality, more complete and structured data, and the redesign of clinical and administrative processes to increase the efficiency and effectiveness of clinicians (Rimmer et al., 2014).

The next section presents an overview of HIS adoption and maturity models.

2.6 HIS Adoption and Maturity Models

Several frameworks for HIS adoption have been reported in the literature (Callen, 2008; Dixon, 1999; Infoway, 2013b; Lau, Hagens, Muttitt, 2007; Lau, Price, Keshavjee, 2011; OntarioMD, 2017). The Technology Acceptance Model (Davis, 1989) and the Information Technology Adoption Model (Dixon, 1999) are two clinical information system models based on behavioural theory. The Technology Acceptance Model focuses on users' acceptance of technology and the impact of technology on this acceptance. Davis proposed that the design of the information system directly influenced perceived usefulness and ease of use (Davis, 1989).

The Information Technology Adoption Model builds on the work of Davis and focuses on users' perceptions of the usefulness of EMRs and the ease of their use to predict the adoption and utilization of the innovation (Dixon, 1999). Furthermore, the Unified Theory of Acceptance and Use of Technology is a relevant framework that has been widely used in technology adoption and diffusion research to assess user intention and behaviour. The framework suggests that four key constructs performance expectancy, effort expectancy, social influence and facilitating conditions, are direct determinants of behavioural intention and ultimately behaviour, and that these constructs are influenced by gender, age, experience, and voluntariness of use (Williams, 2015). The theory is based on previous dominant theories and models that explained information systems usage behaviour such as the Technology Acceptance Model.

A shortcoming of many of the information technology frameworks described above is that they focus on behaviour related to technology and do not take into account organizational and clinical environments where the technology is used. To address this shortcoming, models of health information technology implementation have been developed that attempt to incorporate the organizational and clinical context. One such model is the Contextual Implementation Model, which evaluates health information technology usage from an organizational, clinical, and individual contexts (Callen, 2008). The model focuses on users' requirements and the clinical environment to facilitate the adoption of clinical information systems (Callen, 2008).

Moreover, the Rogers' Diffusion of Innovation Theory has been used to describe diffusion of health information technology (Greiver et al., 2011; Nøhr et al., 2007; Protti et al., 2008; Rahimi et al., 2009). This theory identified five general factors that influence the success of and speed with which an innovation is adopted by individuals: the characteristics of the potential adopters (e.g., employees), the rate of adoption, the nature of the social system, the characteristics of the innovation, and the characteristics of change agents (e.g., managers or professional leaders). This theory also suggests that the characteristics of potential adopters are a key factor in the adoption of innovation, where some adopters may be innovators (i.e., quickest to adopt new ideas), while others may be extreme laggards (i.e., most conservative and actively resistant to the introduction of innovation) (Rogers, 2003).

Canada Health Infoway applied a change management approach and created the Change Management Framework to support clinicians in the successful transition and adoption of HISes (Infoway, 2013b). In 2007, Canada Health Infoway also published a Benefits Evaluation Framework (Lau, Hagens, & Muttitt, 2007) that identified micro-level factors that influence the adoption of health information systems by clinicians in Canada. In 2011, the Clinical Adoption Framework (CAF), which extends Canada Health Infoway's Benefits Evaluation Framework and includes contextual factors such as people, organization, implementation, and the marco environment, was created (Lau, Price, & Keshavjee, 2011). The CAF (see Figure 2.1) proposes that successful clinical adoption of HISes at the micro level depends on the following

dimensions: the quality of the system's performance, information, and support service provided for the HIS; its use and user satisfaction; and net benefits. At the meso level, the people involved, the organization, and the implementation of the HIS have a direct effect on micro-level HIS adoption by health care professionals. At the macro level, successful clinical adoption depends on health care standards, funding and incentives, legislation/policy and governance, and societal, political, and economic trends. (For a detailed description of the dimensions for each level, see Appendix A). This dissertation uses the CAF because it identifies micro, meso, and macro-level factors that influenced EMR success. In addition, the framework was developed to assess the success of EMRs in Canada, which was appropriate for this study as it was conducted in a Canadian context. A shortcoming of the framework is not taking into account the health information system's process of maturity.

OntarioMD developed the EMR Maturity Model (OntarioMD, 2017). This model is based on existing frameworks such as the Change Management Framework and the CAF and was developed to help clinicians optimize their EMR use by evaluating clinicians' level of EMR use (OntarioMD, 2017). The EMR Maturity Model evaluates maturity in terms of how the product is used, and users can measure their maturity level for a certain function (e.g., appointment scheduling, laboratory results) across six maturity levels (see Table 2.1) (OntarioMD, 2017). Thus, this dissertation refers to maturity as the maturity of the user's skillset

and clinical processes in using the HIS rather than the maturity of a product (i.e., type of features implemented).

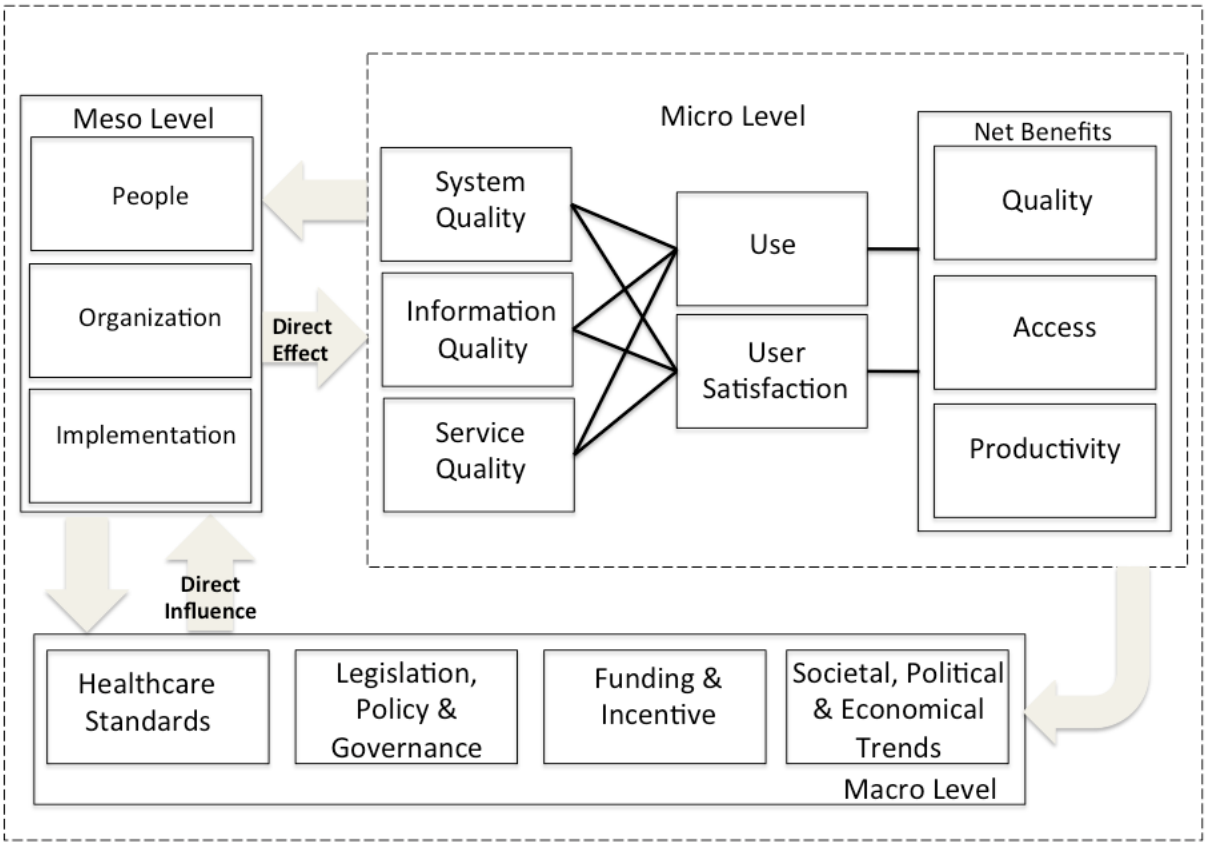

Figure 2. 1 Clinical Adoption Framework

Table 2. 1 OntarioMD EMR maturity model

Level	Criteria	Capabilities
5	Integrate	Use of portals, hubs; attachment to provincial e-health platforms sharing data from the EMR.
4	Population data use	Dashboarding of whole populations, acting upon the whole, performing population analysis at the practice level.
3	Look ahead/predict	Reminders and alerts are used at the point of care. Searches are done regularly and scheduled for review.
2	Early data use	Acting upon the output of episodic searches, quick entry tools, forms, calculators, etc.
1	Enter data	Documentation occurs electronically. Progress notes, forms, and other documents are entered into the EMR.
0	Paper	Processes are primarily paper-based.

2.7 Summary of the Literature

From the studies reviewed, it is evident that EMR features enhance the quality of patient care delivery. Furthermore, the use of advanced EMR features has significant potential to support CDPM. Specifically, the EMR can help (1) identify patients with chronic diseases, (2) assess whether a patient is due for recommended tests or screening procedures, and (3) determine which patients have not achieved evidence-based clinical goals for key measures (i.e., blood pressure control, lipid) (O'Connor et al., 2005). Typically, advanced EMR features such as reminders or recall systems are used to present this information to PCPs (e.g., prompt at the point

of care that a patient is due for a hemoglobin A1C test or a report that lists all diabetic patients who have not had an eye exam in the last 24 months).

In the latest National Physician Survey in 2014, 82% of Canadian PCPs reported using their EMR system to manage their patients' chronic conditions (NPS, 2014b). However, Canada Health Infoway (2013a) estimates that only 3–18% of Canadian PCPs have realized improvements in CDPM or preventive care (e.g., the identification of patients who are at risk or in need of follow-up). Moreover, there is evidence that there has been modest improvement in the use of advanced EMR features in preventative care and disease management, such as electronic reminders prompting follow-up for preventive care and clinical decision support tools (Goetz et al., 2012; Lau et al., 2012). These findings highlight the need to support PCPs in the use of advanced EMR features for CDPM.

The literature review has demonstrated a gap in knowledge of how advanced EMR features are used in managing and preventing chronic illnesses, which is imperative to continued innovation in health care service delivery. By understanding how physicians use EMRs can assist in identifying barriers and facilitating factors that influence the maturity of EMR use. Furthermore, support to enable mature use of EMRs has been identified as a national research priority (Infoway, 2013a). This reveals the opportunity and critical need to examine how to support PCPs in their use of the advanced features of their EMRs for CDPM.

Chapter Three. Methodology

The overarching aim of the dissertation is to explore the mature use of EMRs among PCPs using a multimethod approach. This chapter provides a detailed description of the rationale for the methods used for the systematic review, the qualitative study, and the process mapping study. In addition, the chapter describes the study objectives, study design, data collection and analysis.

3.1. Systematic Review

3.1.1. Objective.

This systematic review aimed to determine the factors (barriers or facilitators) that influence PCPs' mature use of EMRs to support primary care delivery. The specific research question that guided the review was as follows:

- What are the factors that affect the mature use of EMRs by primary care physicians?

3.1.2. Methods.

The systematic review was designed based on the methods proposed in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2019) and was conducted

according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses criteria (PRISMA) (Shamseer et al., 2015). The systematic review protocol was developed a priori to minimize the risk of bias in the review process related to, for example, the authors' selection and inclusion of studies and outcome reporting (Moher, Liberati, Tetzlaff, & Altman, 2009). In accordance with the PRISMA guidelines, our systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) on September 20, 2019 and was last updated on June 30, 2020 (registration number CRD42019137526) (Shamseer et al., 2015).

3.1.3. Search Strategy.

A comprehensive search was conducted using hand and electronic searches in electronic databases and gray literature. The search strategy was developed by an information specialist and the primary investigator (RR) using the inclusion exclusion criteria listed in Table 3.1. The literature search strategies relied on medical subject headings (MeSH) and text terminology related to three core search terms: (1) PCPs, (2) EMRs, and (3) maturity. The following databases were searched without language restrictions: MEDLINE, EMBASE, and PsycINFO. The PROSPERO registry was also searched for ongoing or recently completed relevant systematic reviews.

Other sources of studies were also investigated: Google Scholar was searched using topic keywords (EMR, PCP, maturity), reference lists of eligible studies were hand-searched, citation

analysis using the database Scopus was conducted on key studies, and key journals in the field (International Journal of Medical Informatics, Journal of the American Medical Informatics Association, Journal of Medical Internet Research) were searched for relevant studies. In addition, the thesis gray literature (ProQuest Dissertations and Thesis Global) was searched.

The search strategy included studies published from 1946 to June 13, 2019 (see Appendix B).. Furthermore, the search strategy included studies written in any language to not exclude studies where the abstracts were not written in English but the full texts were in English. However, during full text screening, studies not written in English were excluded due to limited resources to translate the study into English. The search strategy is provided in Appendix B to allow others to replicate the search as per PRISMA guidelines.

3.1.4. Data Selection and Extraction.

The search results were imported into Covidence (a web-based software platform that supports the development of systematic reviews) (Covidence, 2018), which allowed us to remove duplicate studies. Two independent reviewers conducted the first level of screening of the literature, using citation titles and abstracts only to determine potentially relevant studies that met the inclusion criteria (see Table 3.1). Both reviewers had to agree on the ineligibility of a citation for it to be excluded. Finally, 2 independent reviewers screened the full texts of the eligible studies to determine the final set of studies to be included in this review.

The 2 reviewers independently extracted data, with disagreements resolved through consensus. A structured data collection tool developed from a standardized data extraction form by the Cochrane library (Cochrane, 2019) was used to ensure the systematic extraction of data, as the extracted data were used to synthesize the findings. The data collection tool was pilot tested on 5 randomly selected eligible studies. The structured form guided the extraction of key study characteristics, including the country, design, number of participants, data collection procedures, and barriers and facilitators influencing PCPs' mature use of EMRs.

Table 3. 1 Criteria for inclusion of studies

	Inclusion Criteria
Type of study	Studies reporting original primary data that answered the question "what factors affect the mature use of EMRs by PCPs?"
Type of participants	Studies in which the primary user of the EMR was a PCP. For this review, PCPs were defined as medically trained physicians who deliver primary health care. PCPs were considered to include general practitioners, family doctors, primary healthcare doctors, family physicians, and family practitioners.
Intervention	Studies with interventions for the mature use of EMRs by PCPs to support primary care delivery. In this review, the definition of an EMR provided by Canada Health Infoway was used: "A computer-based patient record specific to a single clinical practice" (Infoway, 2020a).
Setting	Studies conducted in any primary health care setting. This review followed the definition of primary health care by the Institute of Medicine: "The provision of integrated, accessible health care services by clinicians who are accountable for addressing a large majority of personal health care needs, developing a sustained partnership with patients and practicing in the context of family and community" (Vanselow, Donaldson & Yordy, 1995).
Language	Studies where the full text is written in English.

3.1.5. Quality Appraisals

Several quality appraisal tools have been used in the literature (Hong et al., 2018; Joanna Briggs Institute, 2020; Critical Appraisal Skill Program, 2020). The Mixed Methods Appraisal Tool (MMAT) used as a checklist for simultaneously appraising and/or describing studies included in systematic mixed studies reviews including original qualitative, quantitative

and mixed methods studies (Hong et al., 2018). As well, the Joanna Briggs Critical Appraisal tool has a separate checklist for appraising studies such case control, case reports, qualitative research, non-randomized experimental studies, randomized controlled trials (Joanna Briggs Institute, 2020). Furthermore, the Critical Appraisal Skills Programme (CASP), which is commonly used in the literature to appraise qualitative research studies, case control studies, and cohort studies. CASP is a methodological checklist, which provides key criteria relevant to a qualitative research studies, cohort studies or case control studies (Critical Appraisal Skills Programme, 2020).

For this study, eligible studies were assessed by the 2 reviewers using the Public Health Ontario meta-tool for the quality appraisal of public health evidence (PHO MetaQAT) (Rosella, Pach, Morgan & Bowman, 2015). Due to the heterogeneity of the design of the eligible studies, the PHO MetaQAT was used, as it was developed to appraise diverse study designs (including research published as gray literature) while ensuring a high degree of rigor. The reviewers independently rated each study for (1) relevancy (the study met the inclusion and exclusion criteria), (2) reliability (there was sufficient reporting on the conduct of the study), (3) validity (measures were used to decrease the likelihood of errors or bias, and the results could be generalized to a wider population), and (4) applicability (the evidence could be applied to public health practice). Any disagreements were resolved by discussion. The authors of the included studies were contacted to obtain further information as needed. Unlike many quality appraisal

tools, the PHO MetaQAT does not use numeric scoring to appraise quality since numerical summary scores mask important details (Rosella, Pach, Morgan & Bowman, 2015). Rather, the PHO MetaQAT is designed to document all important details to provide transparency.

3.1.6. Data Analysis.

Narrative synthesis was chosen as the method of synthesis rather than a statistical meta-analysis or other specialized forms of synthesis because of resource limitations and time constraints. A qualitative narrative synthesis primarily relies on the use of text to summarize and explain the findings of the synthesis (Popay et al., 2006). Narrative synthesis is useful for synthesizing evidence of different types (qualitative, quantitative, etc.) and comparing similarities and differences across studies (Barnett-Page & Thomas, 2009). The findings were synthesized iteratively following the guidelines established by Popay et al. for conducting a narrative synthesis (Popay et al., 2006). Popay et al. (2006) recommended a generic framework that offers various tools and techniques to guide the process of narrative synthesis. The tools and techniques suggested by Popay et al. (2006) helped to increase the transparency of the qualitative narrative synthesis process and the reliability of the findings and conclusions of this review.

Exploring Relationships in the Data

Textual descriptions are one technique recommended by Popay et al. (2006) to compare findings across studies. A review finding is an analytic output (e.g., a theme, category, theory) from a qualitative evidence synthesis that, based on data from primary studies, describes a phenomenon that is covered by the review question (Lewin et al., 2018a). For the synthesis of review findings, textual descriptions were made for each included study to explore the reported influencing factors of PCPs' mature use of EMRs and to identify relationships within and among the studies. Thematic analysis was used to organize and concisely summarize the findings from a large body of evidence (Popay et al., 2006). Text on the factors impacting PCPs' mature use of EMRs was extracted from the studies and entered into a Microsoft Excel spreadsheet. Extracted data were read thoroughly by RR independently to inductively code the data and identify the salient themes (factors) of PCPs' mature use of EMRs (Bree & Gallagher, 2016). The findings were reported in textual format under the major themes, and it was ensured that data were reported in a structured and organized fashion (Popay et al., 2006).

Assessment of Confidence in the Synthesis Findings

Assessing the robustness of the narrative synthesis allowed us to evaluate the strength of the evidence for drawing conclusions about the facilitators and/or barriers of PCPs' mature use of EMRs identified in the synthesis (Popay et al., 2006). The Confidence in the Evidence from Reviews of Qualitative Research (GRADE-CERQual) approach was used to assess each

qualitative review finding (Lewin et al., 2018b). This method has been helpful for decision makers and policy designers who use qualitative evidence to inform policies and interventions related to various topics, such as healthcare (Lewin et al., 2018a). In the GRADE-CerQual approach, 4 components are used to assess confidence in review findings: (1) the methodological limitations of the studies included (Munthe-Kaas et al., 2018); (2) the coherence and fit between data from primary studies and the review findings (Colvin et al., 2018); (3) the adequacy of the data, degree of richness of the data, and the quantity of data supporting a review finding (Glenton et al., 2018); and (4) the relevance of the included studies in terms of whether they reflect the context determined by the review question (Noyes et al., 2018). Furthermore, as per the PRISMA guidelines (Shamseer et al., 2015), the characteristics of eligible studies were presented in a narrative format. The A MeaSurement Tool to Assess Review (AMSTAR) was also used to evaluate the methodological quality of this systematic review (Shea et al., 2017).

3.2. Qualitative Study

3.2.1. Objective.

The overall aim of the qualitative study was to explore the barriers primary care physicians encounter while using advanced EMR features to facilitate CDPM and the facilitators of their use of these features. Furthermore, this study extended the CAF to include primary care physicians' perceptions of how their use of the EMR system had evolved. Thus, the main

contribution of this study was its examination of the CAF and the maturity of EMR use from the perspective of primary care providers, as primary care providers manage chronic illness.

3.2.2 Study Setting and Design.

Based on existing evidence about factors influencing EMR adoption, a qualitative directed content analysis was conducted using the CAF. A directed content analysis is typically used when existing theory or prior research about a phenomenon requires further description to validate or extend a theoretical framework or theory (Hsieh & Shannon, 2005). Thus, we used directed content analysis to extend the CAF. The study was conducted at primary care clinics located in the Canadian province of Ontario.

3.2.3. Study Participants, Sampling, and Recruitment.

Eligible participants were primary care physicians located in Ontario who had used EMRs for at least one year. Purposeful sampling was used to represent individuals of a range of ages (less than 30 years, 30-40 years, 41-50 years, 51-60 years, 61-70 years, and greater than 71 years), of both sexes (female and male), and from different cities in Ontario. Face-to-face interviews were conducted.

The sample size was determined based on data saturation. After 7 interviews, no new ideas were introduced. Nevertheless, 2 more interviews were conducted to validate that saturation had been

reached. A similar study exploring primary care physicians' experience with EMRs also had a sample size of 9 participants (Ludwick &Doucette, 2009).

OntarioMD assisted in recruiting participants by sharing an advertisement about this study with its peer leaders (see Appendix C). Similarly, Ontario academic family practices were contacted to identify participants, which resulted in the Ottawa Hospital Family Health Team reaching out to its members. Recruitment emails were also sent to individual family practices. Individuals expressing interest in the study were sent an email containing information about the study and a consent form (see Appendix D).

3.2.4. Data Collection and Research Instruments.

Data were actively collected between January 2017 and July 2017 by the primary author (RR). In-person interviews were audio recorded. Interviews were approximately 20 min to 60 min and were conducted by using a semistructured interview guide (see Appendix E). The interview guide was pilot tested in July 2016 with a primary care physician.

3.2.5. Conceptual Framework

In this study, the CAF (Lau, Price & Keshavjee, 2011) was used to categorize the study results and explore the barriers and facilitators that primary care physicians encounter when using EMR

features to support CDPM. Although the CAF does not evaluate the maturity of a clinician's HIS use, the framework is appropriate for this study, as it identifies microlevel, mesolevel, and macrolevel factors that influence EMR success.

The CAF proposes that successful clinical adoption of HISs at the microlevel depends on the following dimensions: the quality of the system's performance, information, and support service provided for the HIS; the use of and user satisfaction with the system; and the net benefits of the system. At the mesolevel, the people involved, the organization, and the implementation of the HIS have a direct effect on microlevel HIS adoption by health care professionals. At the macrolevel, successful clinical adoption depends on health care standards; funding and incentives; legislation or policy and governance; and societal, political, and economic trends. A detailed description of the dimensions for each level can be found in Appendix A.

3.2.6. Data Analysis.

The audio recordings of interviews were transcribed verbatim. The directed content analysis approach using the CAF helped determine the initial coding scheme (Lau, Hagens & Muttitt, 2007; Lau, Price, Keshavjee, 2011). Each interview transcript was read line by line; any text that appeared to describe a barrier or facilitator was highlighted (RR). Next, NVivo software, produced by QSR International (2018), was used to help code all highlighted text using

predetermined codes (RR). Data that could not be coded into one of the categories of the CAF were coded with a label that captured the essence of the barrier or facilitator. Finally, 2 team members (RR and SY) independently analyzed the transcripts, and 3 team members (RR, SY, and CK) audited the data analysis findings.

3.2.7. Ethical Considerations.

The University of Ottawa Research Ethics Board (H01-16-02) granted approval for the study (see Appendix F). All participants provided written informed consent before their interview based on the Tri-Council Policy Statement. Participants were informed about the risks, confidentiality, anonymity, conservation of data, and voluntary participation via the consent form. All personal identifiers were removed from the transcripts, and numbers were used to identify participants (e.g., P1, P2…P9); participants were informed that no identifying personal or organizational data would be published and that they had the right to withdraw from the study at any time. All collected data, including the audio recordings, were kept securely in a locked file cabinet. Data will be stored for 5 years after data collection and then destroyed.

3.3. Process Mapping Study

3.3.1. Objective.

Chronic disease prevention and management is complex and dynamic and involves many processes. This study focused on one key area within chronic disease prevention and management, namely, the management of laboratory results. To address the research objective of streamlining primary care physicians' laboratory results management using EMRs, our study applied a qualitative approach in conjunction with lean methods. We aimed to recommend the best common practice for physicians' laboratory results management using EMRs.

3.3.2 Study Design.

Guided by lean principles, this study employed a qualitative approach to map how EMRs and their features are integrated in primary care physicians' work processes to support laboratory results management. To provide a rich description of the workflow, qualitative data were collected through direct observations of primary care physicians using their EMRs to support laboratory results management. Paper-based field notes were taken to identify the people, data, and objects involved in the work process. Following this observation, open-ended questions directed to the primary care physician were used to verify the observations and seek explanations for discrepancies in the data, which was one type of triangulation used in this study to cross-verify the results. The cross-verification of results from multiple sources was also used in a

systematic review of several workflow studies employing ethnographic observation and interviews as a technique to evaluate the quality of the study results (Unertl, Novak, Johnson & Lorenzi, 2010).

For this study, the data were then used to develop a current-state process map for each participant to explore how they integrated EMRs and their features into their laboratory results management. The current-state process maps for each participant were then combined into one comprehensive current-state process map that included the processes that were common among the participants.

The individual and comprehensive current-state process maps were also validated with participants, which added to the validity of our study (Creswell, 2013). The process maps were created in an iterative manner and member checked: participants were involved in the initial review and subsequent reviews of the current-state process maps until a consensus was reached that the process had been correctly and completely mapped. This technique was also used in a systematic review of several workflow studies that reviewed and verified findings with the study subjects to evaluate the quality of the study results (Unertl, Novak, Johnson & Lorenzi, 2010).

The comprehensive current-state process map was useful for exploring where improvements could be made to the physicians' work processes and for developing a future-state process map that streamlined the current-state process.

3.3.3. Study Setting.

The recruitment for this study targeted family physicians in the cities of Ottawa, Toronto, and Hamilton, all located in the province of Ontario. The study population included participants from all models of primary care practice in Ontario (family health team, community health center, independent practice, and the Rural-Northern Physician Group Agreement). All non-general practices were excluded from the study, as were physicians who did not use EMRs in their practice. Patients were also excluded, as the focus was on the processes used by primary care physicians in their clinics.

3.3.4. Participants and Sampling.

Purposeful sampling was used to represent participants of a range of ages, of both sexes, and from all three cities. The stakeholders, OntarioMD (responsible for certifying EMRs in Ontario (OntarioMD, 2011) and the Ottawa Hospital Family Health Team (The Ottawa Hospital, 2008), assisted in recruitment by sharing an advertisement for this study with their members. Additionally, recruitment emails were sent out to individual family practices. Participants who expressed interest reached out to the primary author (RR), from whom they received a copy of the consent forms. The participants included family physicians, both male and female, between the ages of 30 and 70.

3.3.5. Data Collection.

Iterative data collection and analysis occurred from January to July 2017 through direct observations, informal interviews to clarify observations, and the development of workflow models (see Figure 3.1). Data collection and analysis continued until data saturation, i.e., when additional data did not substantially change the analytical results (Tuckett, 2004). Data saturation was achieved with nine primary care physician participants. A previous systematic review of several workflow studies used the data saturation technique to ensure the quality of the study results (Unertl, Novak, Johnson & Lorenzi, 2010).

Data collection tool. Field notes were used to collect the data necessary to develop the process maps indicating how EMR features were integrated into primary care physicians' laboratory work processes. Direct observations of primary care physicians provided a way to purposively seek specific information about their work processes and the technology and people they interacted with. Traditionally, paper-based data collection methods have been used in direct observations of workflows (Unertl, Novak, Johnson & Lorenzi, 2010; Weigl, Müller, Angerer & Hoffmann, 2014; Rollans, Meade, Schmied & Kemp, 2013), while other studies have used electronic-based observational tools in direct observational studies of health professionals (Unertl, Weinger, Johnson, Lorenzi, 2009; Westbrook, Ampt, 2009; Lo, Burke & Westbrook, 2010). In this study, two kinds of paper-based field notes were created, namely, notes with

descriptive information to document factual data and notes with reflective information to record ideas and questions generated during the observations.

Primary care physicians were observed at their workplaces. Observations were performed either in the physician's office or during an appointment in the exam room (the latter with the patient's consent). Observations did not take place after clinical hours. The duration of observations varied from participant to participant and based on the physician's availability. Observations ranged from 3 to 5 hours.

During the observations in the exam room with the patient, the observer (the primary author [RR]) was not able to see the patient's profile on the physician's computer screen. Instead, participants stated which EMR features they were using. In human factors engineering, this "thinking-aloud" approach has proven to be a useful technique in collecting workflow data (Ozkaynak, Unertl, Johnson, Brixey & Haque, 2016). In addition, to avoid making the patient feel uncomfortable, the observer sat on a chair in the exam room, rather than standing, while taking notes. After the observation period, the observer asked the participant open-ended questions to verify the observations and seek explanations for discrepancies in the data.

3.3.6. Data Analysis.

Lean methods involve the use of process mapping as a tool to visualize workflows (Jimmerson, 2009). Process maps were based only on observations of the user of the EMR (i.e., the physician); the actions of the patients were not considered. Thus, only one actor was involved

in the process. The goal of the lean approach is to eliminate waste and improve flow (Plenert, 2012). The more waste that is eliminated, the more efficient the process will be (Plenert, 2012). Process mapping revealed waste in how primary care physicians in Ontario are currently using EMRs and their features to support laboratory test results management.

Lean methods are used to identify eight common categories of waste, which can in turn indicate process deficiencies: (1) overproduction (e.g., more production than is needed or production before it is needed), (2) waiting (e.g., wasted time waiting for the next step in the process), (3) unnecessary transportation (e.g., the unnecessary movement of products or materials), (4) overprocessing (e.g., more work or higher-quality being done than is necessary), (5) inventories (e.g., a backlog of work), (6) unnecessary movement (e.g., people's performance of unnecessary steps), (7) production of defective parts (e.g., data errors, missing information), and (8) underused employee abilities or creativity (Plenert, 2012).

Process mapping illustrates the relationships between the activities, people, data, and objects involved in the production of a specific output. It also shows where improvements can be made (Damelio, 2011). To facilitate this study, we used flowcharts to visually represent the work processes of primary care providers. Flowcharts illustrate the sequence of the performer's work activities to create, produce, or provide a single specific output (Damelio, 2011).

To map the work processes, variables such as input, output, objects, and people were manually determined from the primary data collected during observations. A current-state

process map was constructed for each participant. Additionally, specific symbols were used in the development of the process maps: oval (start or end point), arrow (relationships between shapes), rectangle (a process), and diamond (a decision node). Process mapping was used to examine PCP's clinical workflow for laboratory results management while using an EMR. Analysis of the observation and interview data guided the model development. We identified sequences of routine activities related to laboratory results management, such as the type of EMR feature used and when features were accessed in the process.

3.3.7. Ethical Considerations.

This study has been granted ethics approval from the University of Ottawa Research Ethics Board (H01-16-02) (see Appendix F). After a verbal briefing about the purpose and structure of the study, participants signed a consent form. No personal information was recorded, and participants' names were codified such that their identities were not revealed. Patients also provided written consent to allow the primary author (RR) to conduct observations in the exam room.

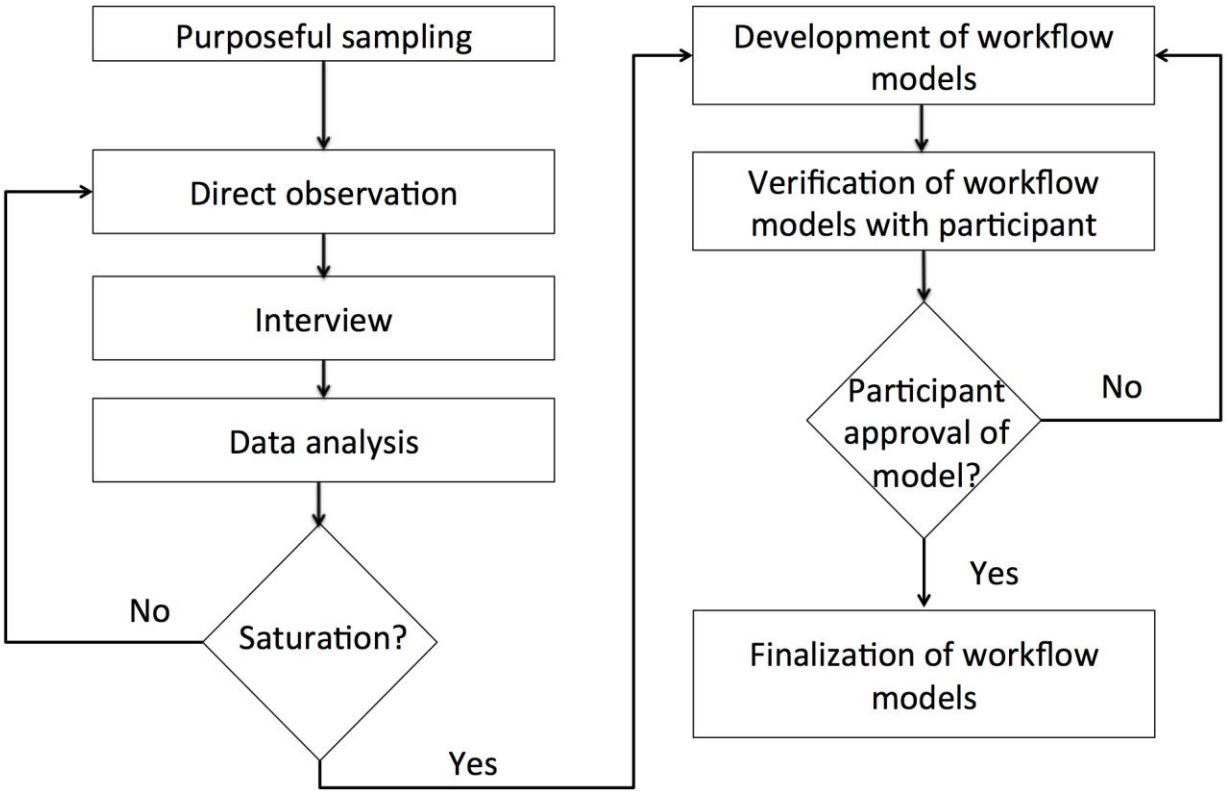

Figure 3. 1 Study design.

Chapter Four. Factors Affecting the Mature Use of Electronic Medical Records by Primary Care Physicians: A Systematic Review

Formatted and Submitted to BMC Medical Informatics and Decision Making Journal

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Abstract

Background: Despite a substantial increase in the adoption of electronic medical records (EMRs) in primary health care settings, the use of advanced EMR features is limited. Several studies have identified both barriers and facilitating factors that influence primary care physicians' (PCPs) use of advanced EMR features and the maturation of their EMR use. The purpose of this study is to explore and identify the factors that impact PCPs' mature use of EMRs.

Methods: A systematic review was conducted in accordance with the Cochrane Handbook. The MEDLINE, Embase, and PsycINFO electronic databases were searched from 1946 to June 13, 2019. Two independent reviewers screened the studies for eligibility; to be included, studies had to address factors influencing PCPs' mature use of EMRs. A narrative synthesis was conducted to collate study findings and to report on patterns identified across studies. The quality of the studies was also appraised.

Results: Of the 1893 studies identified, 14 were included in this study. Reported factors that influenced PCPs' mature use of EMRs fell into one of the following 5 categories: technology, people, organization, resources, and policy. Concerns about the EMR system's functionality, lack of physician awareness of EMR functionality, limited physician availability to learn more about EMRs, the habitual use of successfully completing clinical tasks using only basic EMR features, business-oriented organizational objectives, lack of vendor training, limited resource

availability, and lack of physician readiness were reported as barriers to PCPs' mature use of EMRs. The motivation of physicians, user satisfaction, coaching and peer mentoring, EMR experience, gender, physician perception, transition planning for changes in roles and work processes, team-based care, adequate technical support and training, sharing resources, practices affiliated with an integrated delivery system, financial incentives, and policies to increase EMR use all had a favorable impact on PCPs' use of advanced EMR features.

Conclusions: By using a narrative synthesis to synthesize the evidence, we identified interrelated factors influencing the mature use of EMRs by PCPs. The findings underline the need to provide adequate training and policies that facilitate the mature use of EMRs by PCPs.

Trial registration: PROSPERO CRD42019137526.

Keywords: Electronic health records, Primary health care, General practitioners

Background

As the population ages, the prevalence of chronic disease increases, and primary health care needs are becoming increasingly complex to support [1]. As a result, there is a need to redesign primary care to improve the quality of health care services to effectively support the health of the population while also addressing issues such as rising costs [2]. Policymakers have developed system efficiencies to meet the demands of primary health care and Electronic medical records

(EMRs) are one health information system recommended to facilitate point of care delivery by primary health care professionals [3, 4].

Although the adoption of EMRs has increased internationally [3], the use of advanced EMR features has been limited, particularly in Canada [5]. However, there is evidence of modest improvement in the use of advanced EMR features, such as electronic reminders prompting follow-up for preventive care and clinical decision support tools in preventative care and disease management [6, 7].

"Meaningful use" is a term from the Health Information Technology for Economic and Clinical Health (HITECH) Act passed in the United States [8]. The HITECH act defined "meaningful use" as the use of certified EMR technology in a meaningful manner (e.g., electronic prescribing) to ensure that the certified EMR improved the quality of care [8]. As such, clinicians using certified EMRs must report information on the quality of care, and other measures and specific objectives were set out for clinicians to mature in their use of EMR features [9]. In Canada, "meaningful use" has been used to study mature use of EMRs [10]. In the province of Ontario, OntarioMD, a cooperative owned by the Ontario Medical Association and funded by the provincial government, certifies EMRs and aims to increase the mature use of EMRs in the province [11]. OntarioMD developed the EMR Maturity Model [12] to assist clinicians in the mature use of EMRs. The model is designed so that clinicians can measure their level of EMR use for a certain process (e.g., prevention and screening) across 6 levels of EMR

maturity (0 [paper-based] to 5 [integrated]). It is intended to help clinicians identify their current EMR use level to determine how to help them mature in their EMR use [12]. Likewise, this study defines maturity as the maturation of the user's skill set and clinical processes in using a health information system, rather than the maturity of a product itself (i.e., type of features implemented in an EMR) [13].

Although there are a myriad of factors that have been found to impact EMR adoption and implementation [6, 14, 15], to date, there has been no systematic review exploring the factors impacting PCPs' mature use of EMRs. Studies have highlighted the problem of a tiered EMR ceiling effect [16-18], which occurs when a user is not yet an EMR expert and barriers constrain him or her from learning more advanced EMR features and reaching maturity [18]. Furthermore, providing support to enable maturity in EMR use has been identified as a Canadian research priority [19]. Therefore, there is an opportunity and a critical need to examine how to support PCPs in their use of the advanced features of their EMRs. It is important to identify factors that prevent PCPs from using the full potential of EMRs to enable them to support greater clinical value and quality healthcare service delivery.

Methods

In accordance with the Cochrane Handbook [20], a systematic review was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines

[21]. On September 20, 2019, the protocol for this systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO), and it was last updated on November 30, 2020 (registration number CRD42019137526).

Data sources and search strategy

An information specialist and the primary author (RR) designed the search strategy. The search strategy covered 3 core search terms: (1) PCPs, (2) electronic medical records (EMRs), and (3) maturity. Medical subject headings (MeSH) and thesaurus terms related to the above 3 core search terms were used for the literature search strategies. Three electronic databases were searched, with no language restriction: MEDLINE, PsycINFO, and Embase. The PROSPERO registry was also searched for ongoing or recently completed relevant systematic reviews.

Other sources of studies were also investigated: Google Scholar was searched using topic keywords (EMR, PCP, maturity), reference lists of eligible studies were manually searched, citation analysis using the database Scopus was conducted on key studies, and key journals in the field (International Journal of Medical Informatics, Journal of the American Medical Informatics Association, Journal of Medical Internet Research) were searched for relevant studies. In addition, the gray literature of theses (ProQuest Dissertations and Thesis Global) was searched. The search strategy included studies published from 1946 to June 13, 2019 (see Figure 4.1). Furthermore, the search strategy (shown in Figure 4.1) included studies written in any language

to not exclude studies where the abstracts were not written in English but the full texts were in English. However, during full text screening, studies not written in English were excluded due to limited resources to translate the study into English.

1. Electronic Health Records/
2. ((electronic or computerized) adj2 (health or medical*) adj2 record*).ti,ab,kw.
3. electronic medical record/ or electronic medical record system/
4. medical informatics/ or medical information system/
5. medical information system*.ti,ab,kw.
6. e-health.ti,ab,kw.
7. ehealth.ti,ab,kw.
8. 1 or 2 or 3 or 4 or 5 or 6 or 7
9. physicians, family/ or physicians, primary care/
10. general practitioner/
11. ((primary or family or general) adj2 (physician* or doctor* or practitioner*)).ti,ab,kw.
12. (primary adj2 care).ti,ab,kw.
13. family practice*.ti,ab,kw.
14. general practice/ or family practice/
15. Primary Health Care/
16. general practice*.ti,ab,kw.
17. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
18. (maturity* or maturing).ti,ab,kw.
19. "Diffusion of Innovation"/
20. Diffusion of Innovation*.ti,ab,kw.
21. scalability*.ti,ab,kw.
22. scale up.ti,ab,kw.
23. sustain*.ti,ab,kw.
24. ((matur* or meaningful or optimal* or effective* or advanc* or enhanc* or proficient*) adj3 use*).ti,ab,kw.
25. assimilat*.ti,ab,kw.
26. Attitude to Computers/
27. 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28. 8 and 17 and 27

Figure 4. 1 Ovid MEDLINE database search strategy

Inclusion criteria

As described previously, this review followed the OntarioMD EMR Maturity Model's definition of maturity [12]. As such, the primary outcome is the identification of factors impacting PCPs' mature use of EMRs. Study inclusion and exclusion criteria were created to guide the identification and selection of studies eligible for the systematic review (see Table 1).

Table 4. 1 Study inclusion criteria

	Inclusion Criteria
Type of study	Study designs must report original primary data that answer the question "what factors affect the mature use of EMRs by PCPs?"
Type of participants	The primary user of the EMR must be a PCP. For this review, PCPs are medically trained physicians who deliver primary health care. PCPs include general practitioners, family doctors, primary healthcare doctors, family physicians, and family practitioners.
Intervention	The intervention in question is the mature use of EMRs by PCPs to support primary care delivery. This review uses Canada Health Infoway's definition of an EMR: "A computer-based patient record specific to a single clinical practice" [22].
Setting	Any primary health care setting. This review followed the Institute of Medicine's definition of primary health care: "The provision of integrated, accessible health care services by clinicians who are accountable for addressing a large majority of personal health care needs, developing a sustained partnership with patients and practicing in the context of family and community" [23].
Language	Studies where the full text is written in English.

Data selection and extraction

Search results were imported into Covidence (a web-based software platform that supports the development of systematic reviews) [24] which allowed us to remove duplicate studies. Two independent reviewers conducted the first level of screening of the literature, using citation titles and abstracts only to identify potentially relevant studies that met the inclusion criteria (see Table 4.1). Both reviewers had to agree on the ineligibility of a citation for it to be excluded. Finally, 2 independent reviewers screened the full texts of eligible studies to determine the final set of studies to be included in this review.

The 2 reviewers independently extracted data; any disagreements were resolved through consensus. A structured data collection tool developed from a standardized data extraction form by the Cochrane library [25] was used to ensure the systematic extraction of data, as the extracted data were used to synthesize the findings. The data collection tool was pilot tested on 5 randomly selected eligible studies. The structured form guided the extraction of key study characteristics, including country, design, number of participants, data collection procedures, and barriers and facilitating factors influencing PCPs' mature use of EMRs.

Quality appraisals

The quality of eligible studies was assessed by the 2 reviewers using the Public Health Ontario meta-tool for quality appraisal for public health evidence (PHO MetaQAT) [26]. Due to the heterogeneity of the design of the eligible studies, the PHO MetaQAT was used because it was developed to appraise diverse study designs (including research published as gray literature) while ensuring a high degree of rigor. The reviewers independently rated each study based on its (1) relevancy (the study met inclusion and exclusion criteria), (2) reliability (there was sufficient reporting on the conduct of the study), (3) validity (measures were used to decrease the likelihood of errors or bias, and results could be generalized to a wider population), and (4) applicability (the evidence could be applied to public health practice). Any disagreements were resolved by discussion. Authors of the included studies were contacted, as needed, to obtain further information or clarify any questions about a study. Unlike many quality appraisal tools, the PHO MetaQAT does not use numeric scoring to appraise quality since numerical summary scores mask important details [26]. Instead, the PHO MetaQAT is designed to document all important details to provide transparency.

Data analysis

Narrative synthesis was chosen as the method for synthesis rather than a statistical meta-analysis or other forms of synthesis because of resource limitations and time constraints. A qualitative narrative synthesis primarily relies on the use of text to summarize and explain the findings of the synthesis [27]. Narrative synthesis is useful in synthesizing evidence of different types (qualitative, quantitative, etc.) and useful in comparing similarities and differences across studies [28]. Findings were synthesized iteratively following the guidelines established by Popay et al. [27] for conducting a narrative synthesis. Popay et al. [27] recommend a generic framework that offers various tools and techniques to guide the process of narrative synthesis. The tools and techniques suggested by Popay et al. [27] helped to increase the transparency of the qualitative narrative synthesis process and the reliability of the findings and conclusions of this review.

Exploring relationships in the data

Textual descriptions are one technique recommended by Popay et al. [27] to compare and contrast findings across studies. A review finding is an analytic output (e.g., a theme, category, theory) from a qualitative evidence synthesis that, based on data from primary studies, describes a phenomenon that covers the intent of the review question [29]. For the synthesis of review findings, textual descriptions were performed for each study included to explore reported factors that influence PCPs' mature use of EMRs and identify relationships within and among studies.

Thematic analysis was used to organize and summarize findings in a concise way from a large body of evidence [27]. Text on the factors that impact PCPs' mature use of EMRs was extracted from the studies and entered into a Microsoft Excel spreadsheet. Extracted data were independently read through thoroughly by RR to inductively code and identify the salient themes (factors) for PCPs' mature use of EMRs [30]. Findings were reported in textual format under the major themes, ensuring that data were reported in a structured and organized fashion [27].

Assessment of confidence in the synthesis findings

Assessing the robustness of the narrative synthesis allowed us to evaluate the strength of the evidence for drawing conclusions about the facilitators and/or barriers to PCPs' mature use of EMRs identified in the synthesis [27]. The GRADE-Confidence in the Evidence from Reviews of Qualitative Research (CERQual) approach was used to assess each qualitative review finding [31]. The method has been helpful for decision makers and policy designers who use qualitative evidence to inform policies and interventions about various topics, such as healthcare [29]. The GRADE-CERQual approach uses 4 components to assess confidence in review findings: (1) the methodological limitations of the studies included [32], (2) the coherence and fit between data from primary studies and the review findings [33], (3) the adequacy of data, degree of richness, and quantity of data supporting a review finding [34], and (4) the relevance of the studies included in terms of whether they reflect the context determined by the review question [35].

Furthermore, as per PRISMA guidelines [21], the characteristics of eligible studies are presented in a narrative format. The MeaSurement Tool to Assess Review (AMSTAR) was also used to evaluate the methodological quality of this systematic review [36].

Results

Characteristics of the studies included

Of the 1264 studies screened, 14 studies were included (see Figure 4.2): 5 were conducted in the United States [7, 37-40], 7 were conducted in Canada [10, 16, 18, 41-44], 1 was conducted in Israel [45], and 1 was an international study [3] conducted in 10 countries, including Australia, Canada, France, Germany, the Netherlands, New Zealand, Norway, Switzerland, the United Kingdom, and the United States. The studies were methodologically diverse, including 4 qualitative studies [7, 18, 44, 45], 6 cross-sectional studies [3, 37, 39, 41-43], 3 mixed-methods studies [10, 16, 38], and 1 quantitative descriptive study [40]. These studies were published between 2009 and 2019 (see Table 4.2 for full study details, found at the end of this manuscript).

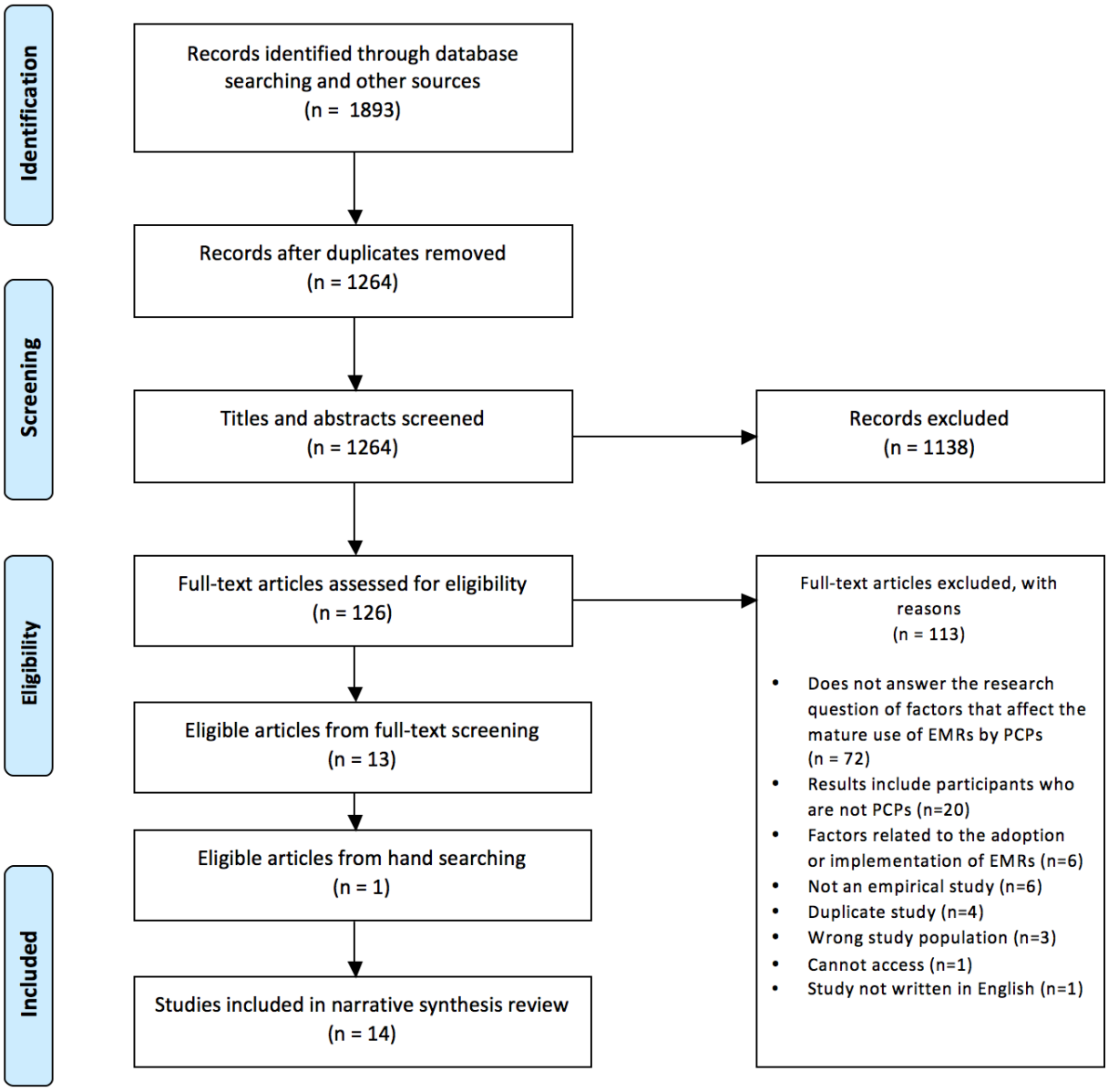

Figure 4. 2 PRISMA flowchart showing the selection process of eligible studies included in the review.

Factors that impact PCPs' mature use of EMRs

The salient factors were found to be best described by 5 overarching themes: technology, people, organization, resources, and policy. The conceptual model shown below (Figure 4.3) portrays how each of these factors is a lens to look at PCPs' mature use of EMRs. Moreover, the CERQual approach uses 4 levels to describe the overall assessment of confidence in a review finding: high, moderate, low, or very low [29]. A summary of the review findings and the CERQual assessments is shown in Table 4.3 found at the end of this manuscript. (See Additional file 1 for overall confidence assessments and descriptions for confidence assessments for each finding.)

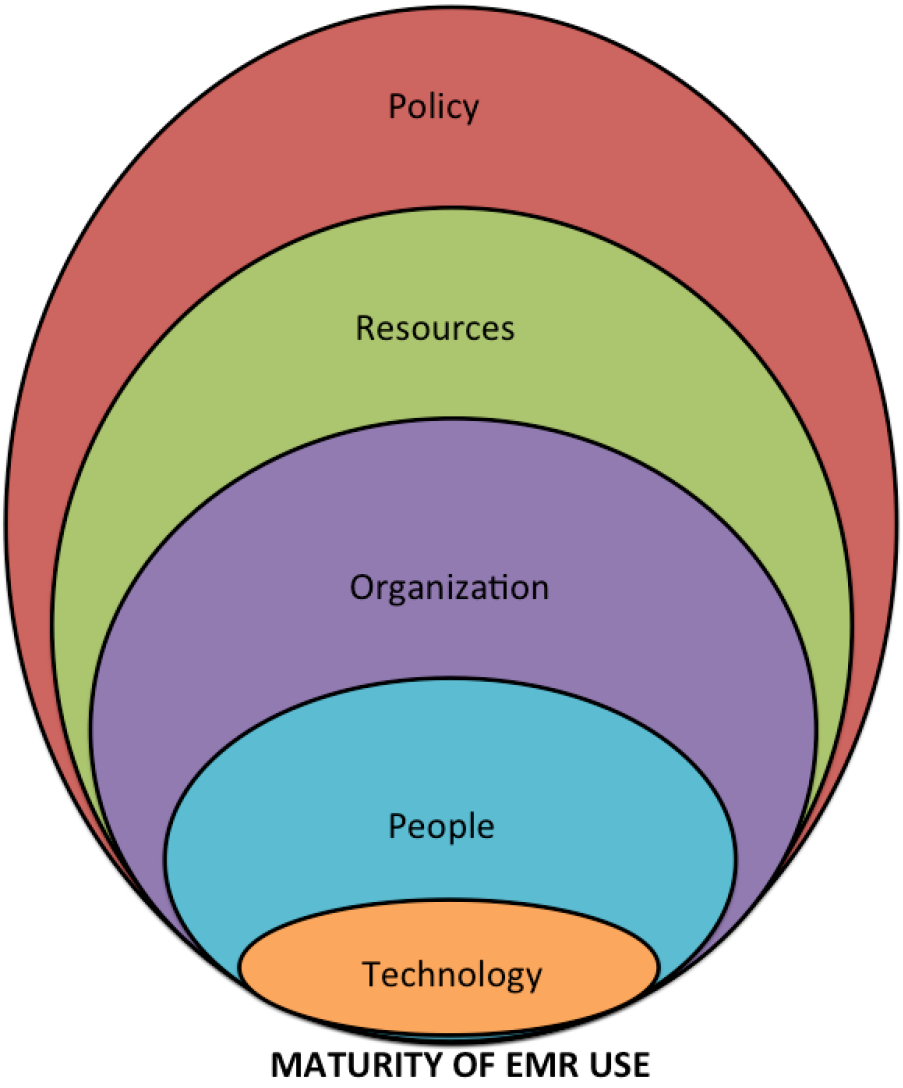

Figure 4. 3 Conceptual model of influential factors in PCPs' mature use of EMRs

Technology

In 4 studies [7, 41, 43, 45], EMR system factors impacted the extent to which physicians used advanced EMR features. In [45], the automaticity of advanced EMR features was found to impede the use of advanced features. This study found that physicians perceived that automaticity in advanced EMR features resulted in errors, where participants (>60%) reported errors such as typos, adding information to the wrong patient chart, and unintentionally selecting an erroneous item (diagnosis or medication) from a scroll-down list [45]. Additionally, participants perceived that the use of predefined templates negatively impacted patient safety, and they preferred typing over using this advanced feature [45]. Furthermore, a study [7] found that the complexity of EMR features led to physicians having trouble understanding how to use EMR functions and how to incorporate these functions into their work routines. In other studies [41, 43, 45], the EMR system's user-friendliness and ease of use were important for fuller usage of the system by family physicians. A study [43] found that EMR systems that had comprehensive clinical functionalities (e.g., providing prescriptions electronically) were used more extensively because physicians saw such features as more useful because these clinical functionalities better supported the main clinical tasks they undertook in primary care settings.

People

A range of individual factors impacting the mature use of EMRs were raised in 8 studies [7, 10, 16, 18, 41, 42, 44, 45].

Physician characteristics

Two studies [10, 41] reported that gender impacted the mature use of EMRs. One of these studies [10] found that the use of EMR features for diabetes care increased most among female PCPs, aged 35–44 with low EMR skills and with the least EMR experience, during the duration of the study [10]. The other study [41] found that the majority of advanced users (those who used 21 out of 24 EMR functions) were female physicians. Furthermore, [41] found that advanced users did not differ significantly from basic users (those who used 11 out of 24 EMR functions on average) in terms of their age and medical experience.

EMR experience

One study [10] found that the use of EMR features for diabetes care increased most among female participants with less EMR experience. This was in contrast to another study that found that advanced users did not differ significantly from basic users in terms of their EMR usage experience [41]. Likewise, in another study [38], no association between extent of EMR

experience and proficiency of EMR use was found. However, this study did find that as physicians' EMR experience and familiarity with the system increased as they became more time efficient in task completion.

Physician perception

Two studies [41, 45] identified physician perception as playing a role in their mature use of EMR systems. One study found that advanced users, compared to basic users, perceived their EMR system to be significantly easier to use with respect to their interactions with patients and other care providers [41]. This study also found that physicians who perceived that neither individual nor organizational performance improvements were due to their use of an EMR system had a more limited understanding of their EMR system's functionality, specifically clinical functionalities, compared to physicians who perceived EMR usage as having a positive influence overall on both their individual performance and their clinic's performance [41]. One other study [45] found that physicians perceived that advanced EMR features (i.e., clinical decision-making aids and alerts of potential adverse drug interactions) reduced their cognitive load, improved communication, improved the quality of care, and enhanced patient safety.

Awareness of EMR functionality

Three studies [7, 16, 18] revealed that a number of physicians were not aware of all the features that were available in their EMRs, specifically advanced features (e.g., e-referral function). This lack of knowledge could be a barrier to increased mature use of EMR.

Physician readiness

Two studies [16, 18] found that a lack of physician readiness was a barrier to the use of advanced EMR features. In one study [16], a lack of readiness was referred to as physicians not wanting to consider advanced features even though the EMR had the capability to do so. The other study [18] used the term "organizational inertia," which also suggests a lack of readiness that was defined as the tendency to be satisfied with the status quo and the outcomes of basic use while consciously ignoring more advanced EMR functionalities.

Physician motivation

One study [44] found that physicians' motivation to improve their use of EMRs was a critical factor that led to success in achieving EMR proficiency. Another study [18] found that when PCPs were not motivated to use the EMR system, they showed a tendency to be satisfied with

the status quo and with the outcomes of basic use, and more advanced EMR functionalities were consciously ignored.

User satisfaction

Two studies [16, 42] found user satisfaction to be a critical component of EMR use. One of the studies [42] determined that EMR user satisfaction was positively and significantly associated with extended EMR use.

Physician availability

Two studies [7, 18] found that having inadequate time to learn more about EMRs inhibited PCPs' mature use of EMRs. One of the studies [18] found that a decrease in PCPs' free time for exploring the EMR and having limited time to invest in continuous learning to better use the features affected their mature use of EMRs. Likewise, some PCPs in the other study [7] reported spending weekends learning new EMR functions, and others expressed reluctance to incorporate additional duties into their busy schedules.

Habitual use

One study [18] also found that physicians could successfully perform their clinical tasks with minimal use of EMRs. This allowed users to ignore potential (IT-based) alternatives and persist in habitual use that had proven to be satisfactory, efficient, and comfortable.

Patient concerns

One study [7] found that some physicians were reluctant to use EMRs because patients were concerned about the impersonal nature of EMR data entry during their medical exam. This resulted in physicians' resistance to moving forward with advanced EMR functions.

Organization

Seven studies addressed several organizational factors that impacted PCPs' mature use of EMRs [3, 7, 18, 37, 39-41].

Practice type

Three studies [37, 39, 41] found that practice type was associated with the mature use of EMRs. In one study [41], a significant proportion of advanced users were found to practice in clinics affiliated with a group of family doctors who worked together and in close collaboration with

other health and social services professionals. Similarly, in another study [39], physicians who were part of an integrated delivery system that had formal arrangements with other practices to share resources or who were eligible for financial incentives were more likely to demonstrate mature EMR use (e.g., multifunctional health information technology capacity, electronic information exchange with other providers, offering patients electronic access to information, appointments, and prescription refills) than physicians without these incentives.

Practice size

In 5 studies [3, 7, 37, 39, 40], practice size was associated with physicians' mature EMR use. In one of these studies [39], practice size was a major determinant of physicians' mature EMR use (e.g., exchanging patient information electronically and providing electronic access to their patients), and there was a 4-fold difference between solo and large practices in achieving multifunctional health information technology capacity (11% vs. 45%). Another study [7] reported that advanced EMR use was more often found in larger practices because of the availability of technical and administrative support. An international study [3] found that Australian, Canadian, New Zealand, Swiss, and US practices with 5 or more full-time-equivalent physicians were significantly more likely to have multifunctional capacity (i.e., using an EMR and at least two electronic functions in the following domains: the generation of patient information, the generation of a patient registry and panel information, order entry management,

decision support) than practices with fewer than 2 full-time-equivalent physicians. In [40], physicians in small primary care practices were found to make robust progress towards meaningful EMR use. In [41], advanced users did not differ significantly from basic users in terms of their practice size and location (urban vs. rural).

Organizational objectives

One study [18] found that the absence or secondary nature of a clinic's EMR assimilation phase (i.e., when the EMR was used on a daily basis and integrated into the organization) when a clinic's operational objectives had been met by the EMR system, was an important factor that prevented mature use. The same study [18] also found that primary health care clinics that wanted to use the EMR to address business-related issues (e.g., operational efficiency) thwarted any effort to extend EMR use to reap more benefits.

Team-based care

Study [7] found that team-based methods such as giving responsibility to nurses or other team members to collect and enter most patient information into the EMRs facilitated the use of advanced EMR features because they allowed physicians to focus on patient care.

Transition planning

One study [7] found that planning for changes in roles and responsibilities, redesigning work processes, and developing up-to-date policies and procedures when implementing advanced EMR features facilitated the advanced use of EMR features in practices. The study also found that practices that did not proactively redesign work processes around new advanced EMR features resulted in physicians' limited use or nonuse of these advanced features because they lacked an understanding of the rationale for advanced feature use.

Resources

Seven studies highlighted the importance of resources as a factor that influenced PCPs' mature use of EMRs [7, 10, 16, 18, 39, 40, 44].

Training

In 4 studies, training impacted physicians' mature use of EMRs [7, 10, 16, 18]. One study [10] found that video tutorial training resulted in an increase in PCPs' use of advanced EMR features for diabetes care. The study also found that the use of EMR features for diabetes care among PCPs who had postimplementation EMR training increased during the duration of the study [10]. The other 2 studies [16, 18][,] found that poor-quality vendor training was a barrier to

physicians' use of advanced EMR features. In one of the studies [16], in which a feedback survey was conducted, several physicians made negative comments regarding the quality of EMR vendor support and training. Furthermore, EMR vendor training was limited, and common support resources available were peer mentors and colleagues [16]. Another study [18],,found that physicians quickly forgot the content of training sessions provided by vendors if they were short and covered only technical functionalities. In addition, training material in these sessions was based on theory rather than practice and focused on basic functionalities that emphasized administrative benefits of EMRs rather than clinical ones. Moreover, the study [18] found that vendors were usually the source of information but that their availability was limited. These vendor based limitations biased physicians towards using only the basic functionalities, which they could easily recall when using the EMR. Interestingly, one study [7] found that practices that successfully used advanced EMR features dedicated time and resources to training and communication on how to use the advanced features (e.g., group training, procedural workflow manuals, 1-on-1 guidance).

Coaching and peer mentoring

Three studies [16, 40, 44] found that support programs that involved coaching from consultants or peer mentoring facilitated the mature use of EMRs by physicians. One study [16] found that physicians who participated in a support program that involved coaching and peer mentoring

reported that their meaningful use of EMR increased, which these physicians believed would positively impact their patients. In another study [44], consultants who used change management techniques (e.g., workflow analysis and corrections) to engage with physicians showed an improvement in physicians' mature use of EMRs. Another study [40], conducted in the US, found that over half of PCPs who enrolled in a regional extension center (REC) program reported meaningful use of advanced EMR features. The RECs supported PCPs in achieving meaningful use of EMRs through education, technical assistance, and coaching.

Sharing resources

Information sharing between practices and other healthcare organizations was highlighted in two studies [7, 39] as a key facilitator of the use of advanced EMR features. In one of the studies [39], PCPs who had shared technical support were more likely to have multifunctional health information technology capacity, electronically exchange patient information, and electronic patient access.

Financial incentives

One study [39] found that physicians who received or were eligible for financial incentives were more likely to be able to electronically exchange patient information with physicians outside of their practice than those not eligible for incentives. However, the study found no association

between incentives and multifunctional health information capacity or patient electronic access. Another study [7] found the costs of upgrading EMR systems to be a barrier in the use of advanced EMR features and highlighted that financial support was key to overcoming this challenge.

Technical support

Study [7] highlighted that adequate technical support (e.g., vendor support, a health information technology department, or an in-house EMR "go-to person") was a critical factor in the advanced use of EMRs because it supported the configuration of new EMR features and staff training.

Resource availability

Study [18] reported that a further barrier to the mature use of EMRs was the paucity of sources of information about EMRs available to PCPs, since vendors were usually the main source of information but were not readily available.

Policy

Policies to increase EMR use are an important factor in EMR use, which was highlighted in only one of the studies. An international study [3] found that small practices in countries that had

collaborative and regional policies to increase the spread and use of health information technology had EMR usage patterns of multifunctional capacity across four domains: the generation of patient information, the generation of patient registry information, order entry management, and decision support functionality.

Discussion

Our systematic review found multiple interrelated factors that influenced the mature use of EMRs by PCPs. Five themes emerged across the 14 studies: technology, people, organization, resources, and policy. Concerns about an EMR system's functionality, utility, ease of use, and technical reliability appeared to deter physicians from using advanced EMR features [7, 45]. As pointed out in one of the studies [43], physicians used particular EMR features more extensively when such features "fit" their main medical tasks. This key point regarding physicians perceiving a lack of fit between EMR systems and their values, priorities, and work practices was echoed in several studies [46-48]. This complements what was raised in a separate study [49], an evidence synthesis that concluded that the challenge of sustaining the use of technology in the healthcare field was due to the fact that many healthcare organizational processes (e.g., team-based care delivery, handovers) were immature, not standardized, and still evolving. This process immaturity makes it difficult for health information technology to support these processes [49].

Individual factors were the most common theme influencing PCPs' mature use of EMRs. Gender appeared to affect the mature use of EMRs [10, 41]. There was mixed evidence

regarding PCPs' EMR experience and mature EMR use. Physicians who perceived that their EMR system was easy to use, reduced their cognitive load, improved communication, improved the quality of care, enhanced patient safety, improved the clinic's workflow, and enhanced the efficiency of physicians made the widest-ranging use of their EMRs [41, 45]. A lack of physician awareness of EMR functionality and the lack of physician readiness to learn advanced features were issues emphasized in another study [17]. Physician motivation to advance their EMR use and user satisfaction were both found to be critical factors associated with mature EMR use [16, 18, 42, 44]. Furthermore, limited physician willingness to learn more advanced EMR features [16, 18], the habitual use of performing clinical tasks using basic functions [18], and patient concerns about the impersonality of the physician entering data during a consultation [7], were factors that were also found to prevent the maturation of EMR use.

Organizational factors were another theme that emerged from the studies. We found that practices affiliated with an integrated delivery system were associated with physicians who were advanced EMR users [37, 39, 41]. However, mixed reviews were found regarding practice size and physicians' mature EMR use [40, 41], where larger practices achieved more advanced EMR use compared to solo practices [3, 7, 39]. However, as pointed out by Schoen et al. [3], even small practices can achieve mature EMR use if given health policy support and appropriate incentives. Organizational objectives were also found to influence PCPs' mature use of EMRs. One study [18] reported that when a clinic's objectives were overshadowed by operational

objectives (e.g., operational efficiency), the effort by PCPs to achieve mature use of EMRs was thwarted. Another study [7] highlighted the importance of using team-based methods (e.g., giving responsibility to nonphysician staff to collect and enter patient data into EMRs) and transition planning (e.g., developing new processes and workflow procedures when implementing advanced features) to facilitate the use of advanced EMR features by PCPs.

Another dominant theme in this review was resources such as peer mentors or colleagues, coaching consultants, technical support, training, sharing resources with other healthcare organizations, and financial incentives, all of which had a favourable impact on PCPs' use of advanced EMR features [7, 10, 16, 39, 40, 44]. On the other hand, limited and poor training by vendors was found to be a barrier to the use of advanced EMR features by PCPs [16, 18]. We also found that efforts made to provide adequate training both during and post EMR implementation that focused on clinical rather than administrative benefits had a favourable impact on PCPs' mature use of the system [7, 10, 16, 18]. Finally, concerns about limited resources for learning more about EMRs and their features were also reported as a barrier [18].

Our findings highlight the key factors that affect the mature use of EMRs by PCPs. To enhance the mature use of EMRs we suggest focusing on the following factors. First, future EMR implementation programs must provide an opportunity for end-users to play an active role in the design process from the outset, which may help to address the barrier of a lack of fit between EMR features and clinicians' priorities. Moreover, this approach could alleviate the

functionality barriers of EMR systems and physicians' concerns regarding the impersonality of their interaction with patients when using an EMR during a consultation. Second, providing adequate training that meets the needs of the end user could limit the habitual use of only basic EMR features and facilitate physician awareness of advanced EMR functionality and physician readiness to use advanced features. OntarioMD has developed a peer leader program that connects practices with clinicians who are superusers to support a practice's mature use of EMRs [50]. Finally, initiatives that encourage physicians to join an integrated delivery system should be implemented, since out study revealed that this type of practice influences the mature use of EMRs by clinicians. One such initiative is Ontario's funding of family health teams (a team-based model) [51] to assist with EMR use [52, 53]. Financial incentives could be one strategy to promote integrated delivery system practices, which may also encourage the use of EMR supported team-based models. Moreover, the implementation of collaborative and regional policies that provide technical and financial incentives (e.g., grants or reimbursements) could influence clinics to orient their organizational objectives towards maturing physicians' EMR use rather than being business-oriented. In addition, policies that assist clinics in transition planning to develop new processes and workflow procedures when implementing advanced EMR features would be advantageous. Thus, collaborative and regional policies that support increased EMR use are another strategy to further the mature use of EMRs by PCPs. This was the case in the United States with the introduction of the "meaningful use" guidelines where empirical evidence

shows positive results on EMR usage among physicians [54]. Last, the factors identified in this study operate interdependently and should not be taken into account in static isolation; how these key factors change over time should be considered when observing changes in the level of mature EMR use [55, 56]. Therefore, a key recommendation is to perform a longitudinal analysis on primary care practices to measure the progress of these maturity factors over time. This will allow monitoring of the progress of maturity of EMR use by primary care physicians while also taking into account the different maturity stages of an individual user.

Limitations and strengths

One strength of our review is that the systematic review methodology we used was appraised using the AMSTAR instrument and rated as meeting 14 out of 16 criteria [36, 57]. In terms of the 2 missing items, they were not applicable because we did not conduct a meta-analysis (methods used to combine the findings of appropriate studies), and we did not assess publication bias. A limitation of our review is the small number of studies identified after exclusion (i.e., 14 eligible studies). One of the reasons for this low count is that our review focused on PCPs, which may limit the generalizability of our findings to other health care professionals and beyond primary healthcare [17, 58]. However, as highlighted in previous studies [15, 59], the literature in this field may be poorly referenced within bibliographic databases because terminology is not standardized, and there is no taxonomic consensus related to health information technologies

[60]. This may also explain the limited number of eligible studies retrieved. Additionally, most studies included were conducted in North America, which is not surprising since the concept of meaningful use originated in the US and was developed vis-à-vis mature EMR use in Canada. Furthermore, the term "mature EMR use" was not consistent among studies, which may also have contributed to the limited number of studies that were included. There may have been studies on EMRs and primary care that are not included in this review because they refer to physician factors or contextual issues as something other than maturity. Thus, a key finding from our study is the need for a common terminology to define EMR maturity.

Conclusions

The evidence provided by the studies in this review demonstrates that there are several linked factors that influence the mature use of EMRs by PCPs that could usefully inform future initiatives to sustain health information technologies within a primary care setting. Policymakers and vendors need to be aware that a primary care setting is a complex, dynamic environment, and initiating strategies that are informed by these factors have the potential to support the mature use of EMR by PCPs.

List of abbreviations

EMR: Electronic Medical Record; PCP: Primary Care Physician; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses; PHO MetaQAT: Public Health Ontario Meta quality appraisal tool.

Additional information

Additional file 1.xlsx. Confidence assessments. Assessment of confidence in synthesis findings.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

All data generated or analyzed during this study are available in this published article and its supplementary information file.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

RR, SY, JM, and CK contributed to the development and design of the protocol. RR is the primary investigator. She conceived, led, and coordinated the development and writing of the manuscript. RR conducted the electronic database searches, screened titles, abstracts and full-text papers, extracted relevant data, quality assessed eligible papers, and conducted narrative synthesis of the papers included. SY, JM, and CK participated throughout the development and writing of the manuscript by contributing intellectual content and feedback on drafts of the manuscript. All authors read and approved the final manuscript.

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Tables

Figure 4. 2 Characteristics of eligible studies

Author (year), country	**Design**	**Sample size of PCPs**	**Data collection**
Audet et al. (2014), US [39]	Cross-sectional study	1012	• Self-administered, structured questionnaire
Clarke et al. (2016), US [38]	Mixed-model approach combining qualitative and quantitative research methods	16	• Video analyses • Qualitative participant debriefing sessions (narrative feedback) • Quantitative performance measures (percent task success, time-on-task, mouse clicks, and mouse movements)

			• System usability scale (a survey instrument that allows physicians to rank the system's usability)
DesRoches et al. (2013), US [37]	Cross-sectional study	1164	• Self-administered, structured questionnaire
Goetz et al. (2012), US [7]	Qualitative methods	14	• Telephone interviews • On-site visits involving interviews and observation • National Survey of Physician Organizations
Jones et al. (2018), Canada [44]	Qualitative methods, observational study	6	• Semistructured interviews using the EMR Progress Assessment survey tool • Observations of data quality in EMRs and of physician's workflow
Lynch et al. (2014), US [40]	Quantitative methods, descriptive study	101584	• From 10 databases: Administrative data from Regional Extension Center program's customer relationship management database merged with 9 other secondary data source databases
Paré et al. (2015), Canada [41]	Cross-sectional study	331	• Self-administered structured questionnaire
Randhawa et al. (2018), Canada [10]	Mixed-model approach combining qualitative and	18	• Survey, questionnaire • Follow-up interviews

	quantitative research methods		
Raymond et al. (2015), Canada [42]	Cross-sectional study	331	• Self-administered structured questionnaire
Raymond et al. (2019), Canada [43]	Cross-sectional study	331	• Self-administered structured questionnaire
Schoen et al. (2012), 10 countries (Australia, Canada, France, Germany, Netherlands, New Zealand, Norway, Switzerland, UK, US) [3]	Cross-sectional study	Sample sizes of PCPs ranged from 500 to more than 2000 for the 10 countries	• Phone interviews • Mail surveys using a questionnaire
Shachak et al. (2009), Israel [45]	Qualitative methods	25	• Semistructured interviews • Field observations
Trudel et al. (2017), Canada [18]	Qualitative methods	15	• Semistructured interviews • Field notes from observations • Consultation of relevant documents (e.g., user manuals)
Watt (2014), Canada [16]	Mixed-model approach combining qualitative and quantitative research methods	29	• Questionnaire, survey • Notes from action plans developed with coach and physician • Clinical Value Model (CVM) assessment tool (86 questions, subjective assessment tool administered by the coach) • CVM feedback survey (web-based survey for physicians to complete) • Notes from practice optimization plan

Table 4. 3 Summary of narrative synthesis findings

Review Findings (subthemes and summaries)	Contributing Studies	CERQual Confidence in the Evidence
Technology		
EMR system's functionality – user-friendliness of EMR system, ease of use, and the comprehensiveness of clinical functionalities that fit the main medical tasks of PCPs impacted their use of advanced EMR features.	Shachak et al. [45], Raymond et al. [43], Paré et al. [41], Goetz et al. [7]	Moderate confidence
People		
Physician characteristics – gender was found to have an impact on the mature use of EMRs; advanced EMR features were more often used by female physicians.	Randhawa et al. [10], Paré et al. [41]	Low confidence
EMR experience – use of advanced EMR features increased most among female PCPs who had the least EMR experience.	Randhawa et al. [10]	Very low confidence
Physician perception – PCPs who perceived that the use of advanced EMR features would have a positive effect on their individual performance (e.g., communication, interaction with patients and other care providers) and their clinic's performance (e.g., quality of care and patient safety) used advanced EMR features.	Paré et al. [41], Shachak et al. [45]	Low confidence

Awareness of EMR functionality – PCPs' lack of awareness of all the available advanced EMR features could be a barrier to the maturing of their use of EMRs.	Watt [16], Trudel et al. [18], Goetz et al. [7]	Moderate confidence
Physician readiness – lack of physician readiness to use advanced EMR features even though they had the capability could be a barrier to their mature use of EMRs.	Watt [16], Trudel et al. [18]	Low confidence
Physician motivation – PCPs' motivation to improve and become proficient in using EMRs was found to facilitate their mature use of EMRs. Whereas PCPs that were not motivated continued to use basic functions and consciously ignored advanced EMR features.	Jones et al. [44], Trudel et al. [18]	Moderate confidence
User satisfaction – EMR user satisfaction could facilitate the mature use of EMRs.	Watt [16], Raymond et al. [42]	Moderate confidence
Physician availability – inadequate time to learn more advanced EMR features and to invest in continuous learning to better use them was found to prevent mature use by PCPs.	Trudel et al. [18], Goetz et al. [7]	Low confidence
Habitual use – successful performance of clinical tasks with only basic use of EMRs was found to be a barrier to mature use of EMRs.	Trudel et al. [18]	Very low confidence
Patient concerns – the impersonality of EMR data entry during medical exams led to physicians' dissatisfaction with	Goetz et al. [7]	Very low confidence

and resistance to using advanced EMR features.		
Organization		
Practice type – advanced EMR users have been shown to be affiliated in a practice with an integrated delivery system where PCPs collaborate closely with other health and social services professionals, that shares resources, and that is eligible for financial incentives.	Audet et al. [39], Paré et al. [41], DesRoches et al. [37]	Moderate confidence
Practice size – PCPs in larger practices (5 or more full-time-equivalent PCPs) were more likely to be advanced EMR users compared to PCPs from smaller practices (less than 2 full-time PCPs).	Audet et al. [39], Schoen et al. [3], Goetz et al. [7]	Moderate confidence
Organizational objectives – clinical objectives to use EMRs on a daily basis and integrate them into the organization were absent or secondary once a clinic's operational objectives for EMR use had been met. In addition to a business-oriented motivation, thwarted any effort to extend EMR use was found to be a barrier to the mature use of EMRs.	Trudel et al. [18]	Very low confidence
Team-based care – team-based methods such as assigning responsibility to nurses or other staff to enter patient data into EMRs or retrieve it allowed physicians to focus on patient care and facilitated the use of advanced EMR features.	Goetz et al. [7]	Very low confidence

Transition planning – planning for changes in roles and responsibilities, redesigning work processes, and developing up-to-date policies and procedures in a practice when implementing advanced EMR features facilitated their advanced use.	Goetz et al. [7]	Very low confidence
Resources		
Vendor training – limited and poor quality vendor training such as short training sessions and material based on theory rather than clinical practice, biased physicians towards using only basic EMR features.	Watt [16], Trudel et al. [18]	Low confidence
Training – adequate training (e.g., video training, training focused on clinical benefits, group training, procedural work flow manuals, 1-on-1 guidance) increased PCPs' use of advanced EMR features.	Randhawa et al. [10], Goetz et al. [7]	Low confidence
Coaching and peer mentoring – coaching by consultants and peer mentoring increased PCPs' mature use of EMRs.	Lynch et al. [40], Watt [16], Jones et al. [44]	Moderate confidence
Sharing resources – sharing technical assistance was found to be associated with multifunctional health information technology capacity, electronically exchanging patient information, and electronic patient access.	Audet et al. [39], Goetz et al. [7]	Very low confidence
Financial incentives – PCPs that received or were eligible for financial incentives were more likely to be able to use advanced	Audet et al. [39], Goetz et al. [7]	Very low confidence

EMR features (e.g., electronically exchanging patient information with physicians outside of their practice)		
Technical support – adequate technical assistance, such as EMR vendors, a health information technology department, or an in-house EMR "go-to person" who supported the configuring of new EMR features and training staff, was a critical factor in the use of advanced EMR features.	Goetz et al. [7]	Very low confidence
Resource availability – limited sources of information about EMRs was found to prevent their mature use.	Trudel et al. [18]	Very low confidence
Policy		
Policies to increase EMR use – PCPs from small practices in countries that had collaborative and regional policies to increase the spread and use of health information technology were shown to have multifunctional capacity.	Schoen et al. [3]	Low confidence

Figure legends

Figure 4.1. Ovid MEDLINE database search strategy

Figure 4.2. PRISMA flowchart showing the selection process of eligible studies included in the review

Figure 4.3. Conceptual model of influential factors in PCPs' mature use of EMRs

Chapter Five. Primary Care Physicians' Experience Using Advanced Electronic Medical Record Features to Support Chronic Disease Prevention and Management: Qualitative Study

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Abstract

Background: Chronic diseases are the leading cause of death worldwide. In Canada, more than half of all health care spending is used for managing chronic diseases. Although studies have shown that the use of advanced features of electronic medical record (EMR) systems improves the quality of chronic disease prevention and management (CDPM), a 2012 international survey found that Canadian physicians were the least likely to use 2 or more EMR system functions. Some studies show that maturity vis-à-vis clinicians' EMR use is an important factor when evaluating the use of advanced features of health information systems. The Clinical Adoption Framework (CAF), a common evaluation framework used to assess the success of EMR adoption, does not incorporate the process of maturing. Nevertheless, the CAF and studies that discuss the barriers to and facilitators of the adoption of EMR systems can be the basis for exploring the use of advanced EMR features.

Objective: This study aimed to explore the factors that primary care physicians in Ontario identified as influencing their use of advanced EMR features to support CDPM and to extend the CAF to include primary care physicians' perceptions of how their use of EMRs for performing clinical tasks has matured.

Methods: Guided by the CAF, directed content analysis was used to explore the barriers and facilitating factors encountered by primary care physicians when using EMR features. Participants were primary care physicians in Ontario, Canada, who use EMRs. Data were coded using categories from the CAF.

Results: A total of 9 face-to-face interviews were conducted from January 2017 to July 2017. Dimensions from the CAF emerged from the data, and 1 new dimension was derived: physicians' perception of their maturity of EMR use. Primary care physicians identified the

following key factors that impacted their use of advanced EMR features: performance of EMR features, information quality of EMR features, training and technical support, user satisfaction, provider's productivity, personal characteristics and roles, cost benefits of EMR features, EMR systems infrastructure, funding, and government leadership.

Conclusions: The CAF was extended to include physicians' perceptions of how their use of EMR systems had matured. Most participants agreed that their use of EMR systems for performing clinical tasks had evolved since their adoption of the system and that certain system features facilitated their care for patients with chronic diseases. However, several barriers were identified and should be addressed to further enhance primary care physicians' use of advanced EMR features to support CDPM.

Keywords

electronic health record; chronic disease; primary health care; medical informatics

Introduction

Background

According to the World Health Organization, by 2020, chronic diseases will account for 73% of all deaths and 60% of the global burden of disease [1]. The World Health Organization recommends that chronic disease prevention must focus on controlling risk factors such as high blood pressure and tobacco use [1].

Electronic medical records (EMRs) are one of many initiatives available in high-income countries to assist in addressing these risk factors. In a systematic review, approximately 67% of studies showed that EMRs have a positive effect on preventive care, and about 57% of studies found that EMRs contribute to a modest improvement in disease management [2].

Electronic reminder features for preventive or follow-up care automate reminders for specific tests (eg, vaccinations and blood tests) based on recommended guidelines [3]. Advanced EMR features, such as electronic reminders, have been shown to support chronic disease prevention and management (CDPM). When EMR reminders were combined with access to EMR information (eg, history of hypertension and cardiovascular disease), 28% of the patient population was found to be at risk for undiagnosed type 2 diabetes [4].

A grounded theory study of EMR usage ranked EMR features from basic to advanced [5]. Advanced features included automated reminders for tests and screening; using decision support tools, such as a cardiovascular risk tool; using a recall system to search for patients with a specific condition; creating customized templates, such as diabetic flow sheets; and using a graph feature to view the trend of a patient's test results over time [5].

Statement of the Problem

Not all physicians use the advanced features of EMR systems to support CDPM. A 2012 study showed that Canadian physicians were the least likely to use at least two EMR functions [6]. Thus, there is a gap in our understanding of the barriers to and facilitating factors of the use of advanced features in EMR systems.

Factors That Impact the Adoption of Electronic Medical Records

Much of the literature has focused on the factors that contribute to successful EMR adoption. Studies have discussed the need for EMR champions and staff participation to encourage adoption [7-9]. Rogers' diffusion of innovations theory suggests that the characteristics of potential adopters are also a key factor for EMR adoption [10].

In addition, studies have identified the importance of providing adequate education and training to support EMR adoption [11,12]. In the Canadian province of Ontario, the Association of Family Health Teams developed a program comprising individuals known as quality

improvement decision support specialists (QIDSS) who were available on-site to assist teams to access and better use EMR data to improve care [13].

Furthermore, some studies have highlighted the importance of advancing the level of health information system (HIS) use to obtain improved clinical outcomes and have suggested that benefits grow over time as users gain experience, as improvements are made in systems, and as workflows are adjusted to users' needs [14,15]. A Canadian study in Ontario assessed the progress in the use of advanced EMR features and found a direct correlation between years of EMR use and EMR maturity [14]. Thus, in evaluating the use of advanced features of EMR systems, it is important to consider how the use of EMR systems by clinicians has evolved since EMR adoption.

Conceptual Framework

In this study, the Clinical Adoption Framework (CAF) [16] was used to categorize the study results and to explore the barriers and facilitators that primary care physicians encounter when using EMR features to support CDPM. Although the CAF does not evaluate the maturity of a clinician's HIS use, the framework is appropriate for this study as it identifies microlevel, mesolevel, and macrolevel factors that influence EMR success.

Several frameworks for HIS adoption have been reported in the literature [16-21]. OntarioMD, a cooperative owned by the Ontario Medical Association and funded by the provincial government, is responsible for certifying EMRs in Ontario [22]. OntarioMD developed the EMR Maturity Model [21] to help clinicians optimize their EMR use by evaluating their level of EMR use. The model evaluates maturity in terms of how the product is used, and users can measure their maturity level for a certain function (eg, appointment scheduling and laboratory results) across 6 maturity levels [21]. Thus, this study refers to maturity as the maturity of the user's skill

set and clinical processes in using the HIS, rather than the maturity of a product (ie, type of features implemented). The EMR Maturity Model is based on existing models such as the CAF.

The CAF proposes that successful clinical adoption of HISs at the microlevel depends on the following dimensions: the quality of the system's performance, information, and support service provided for the HIS; its use and user satisfaction; and net benefits. At the mesolevel, the people involved, the organization, and the implementation of the HIS have a direct effect on the microlevel HIS adoption by health care professionals. At the macrolevel, successful clinical adoption depends on health care standards; funding and incentives; legislation/policy and governance; and societal, political, and economic trends. A detailed description of the dimensions for each level can be found in previous studies [16,17,23].

Purpose of the Study

This study explored the barriers primary care physicians encounter while using advanced EMR features to facilitate CDPM and the factors facilitating their use of these features. Furthermore, this study extends the CAF to include primary care physicians' perceptions of how their use of the EMR system had evolved. Thus, the main contribution of this study was looking at the CAF and the maturity of EMR use from the perspective of primary care providers, as they are the ones managing chronic illness.

Methods

Study Setting and Design

On the basis of existing evidence about factors influencing EMR adoption, a qualitative directed content analysis was conducted using the CAF. A directed content analysis is typically used when existing theory or prior research about a phenomenon needs further description to validate

or extend a theoretical framework or theory [24]. Thus, we used directed content analysis to extend the CAF.

The study was conducted at primary care clinics located in the Canadian province of Ontario. Although there are various EMR systems available in Ontario, the most common systems used at primary care clinics are PS Suite EMR produced by Telus Health [25], Nightingale On Demand produced by Telus Health [26], IndiviCare produced by Indivica [27], and OSCAR produced by OSCAR EMR Inc. [28]. Advanced EMR features available in these systems include but are not limited to the following:

- Drug databases that provide dosing information, administration, and medication allergy alerts.
- Hospital Report Manager [29], an Ontario provincial feature used to electronically integrate patient reports (eg, medical records and diagnostic imaging reports) from hospitals and specialty clinics directly into a patient's chart.
- Ontario Laboratories Information System (OLIS) that automatically receives laboratory results from hospitals directly into the patient's chart [30].
- Electronic fax to electronically receive faxed documents into EMRs.

Study Participants, Sampling, and Recruitment

Eligible participants were primary care physicians located in Ontario who had used EMRs for at least one year. Purposeful sampling was used to represent a range of ages (less than 30 years, 30-40 years, 41-50 years, 51-60 years, 61-70 years, and greater than 71 years), sexes (female and male), and individuals from different cities in Ontario. Face-to-face interviews were conducted.

Data saturation determined the sample size. After 7 interviews, no new ideas were being introduced. Nevertheless, 2 more interviews were conducted to validate that saturation had

occurred. A similar study exploring primary care physicians' experience with EMRs also had a sample size of 9 participants [31].

OntarioMD assisted in recruiting participants by sharing an advertisement about this study with its peer leaders. Similarly, Ontario academic family practices were contacted to identify participants, resulting in the Ottawa Hospital Family Health Team reaching out to its members. Recruitment emails were also sent to individual family practices.

Data Collection and Research Instruments

Data were actively collected between January 2017 and July 2017 by the primary author (RR). In-person interviews were audio recorded. Interviews were approximately 20 min to 60 min and were conducted by using a semistructured interview guide (Appendix E). The interview guide was pilot-tested in July 2016 with a primary care physician.

Data Analysis

Audio recordings of interviews were transcribed verbatim. The directed content approach using the CAF helped determine the initial coding scheme [16,17]. Each interview transcript was read line by line; any text that appeared to describe a barrier or facilitating factor was highlighted (RR). Next, NVivo software produced by QSR International [32] was used to help code all highlighted text using predetermined codes (RR). Data that could not be coded into one of the categories of the CAF were coded with a label that captured the essence of the barrier or facilitating factor. Finally, 2 team members (RR and SY) independently analyzed transcripts, and 3 team members (RR, SY, and CK) audited the data analysis findings.

Ethical Considerations

The University of Ottawa Research Ethics Board (H01-16-02) granted approval for the study. All participants provided written informed consent before their interview; no personal information was recorded.

Results

Participant Characteristics

Table 5.1 summarizes the sample and participant characteristics. All participants' practices were located in an urban setting in Ontario. Participants' experience in using an EMR system ranged from 3 to 15 years. Overall, 5 of the participants were part of a group practice using the family health organization's capitated payment model, 3 of the participants were from a family health team (FHT) practice model, and 1 participant was from an independent practice. In addition, 5 of the participants identified themselves as the information technology (IT) leader in their clinic. A total of 4 participants used the EMR system PS Suite, 3 used IndiviCare, and 1 worked with Nightingale On Demand.

Table 5.1 Respondents' characteristics.

Participants	Age range (years)	Sex	Primary care model	Experience using electronic medical records (years)	Information Technology lead
P1	51-60	Male	FHT[a]	15	Yes
P2	61-70	Female	Independent practice	3	No
P3	61-70	Male	FHT	10	Yes
P4	41-50	Female	FHO[b]	7	Yes
P5	30-40	Male	FHO	7	Yes
P6	51-60	Male	FHO	15	Yes
P7	30-40	Female	FHT	4	No
P8	41-50	Male	FHO	4	No
P9	61-70	Female	FHO	9	No

[a]FHT: family health team.

[b]FHO: family health organization.

Patterns from the data were categorized into themes. In this study, themes refer to barriers and facilitating factors that influenced participants' use of advanced EMR features. A total of 10 themes emerged from the data: 9 themes directly mapped to the dimensions of the CAF and 1 new theme was derived from our analysis. The dimensions from the framework that directly mapped to the 9 themes were system quality; information quality; service quality; user satisfaction; net benefits; people; organization; legislation, policy, and governance; and funding and incentives. Figure 5.1 shows the dimensions from the CAF that emerged from the data and the 1 new dimension (maturity of EMR use) that was derived from our analysis.

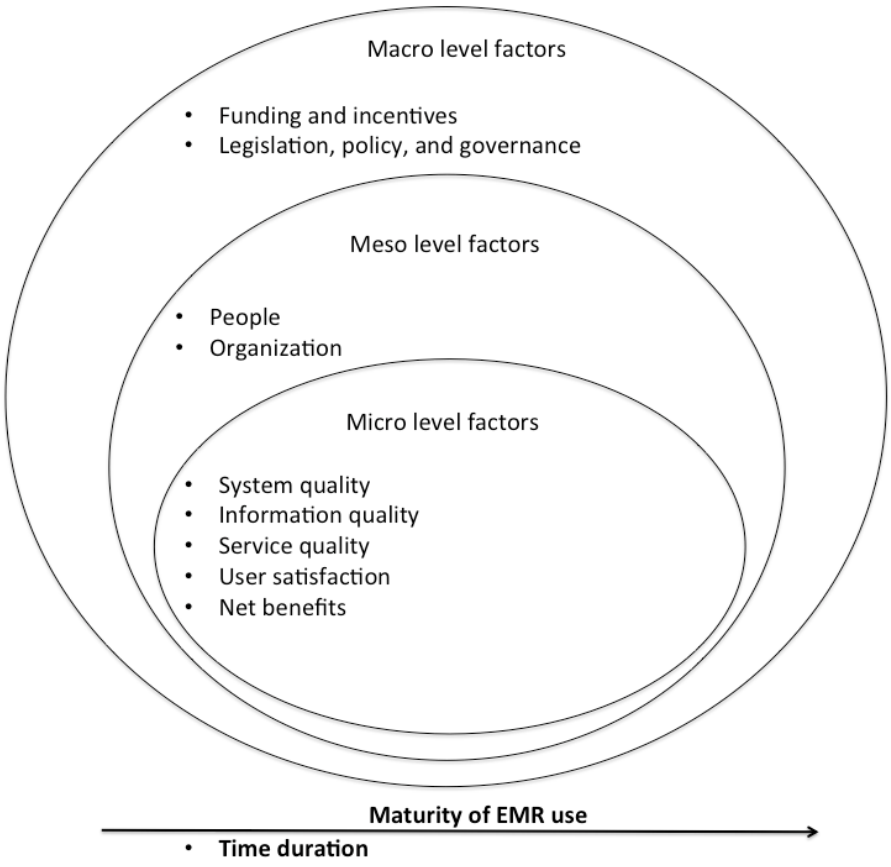

Figure 5.1. Dimensions emerging from the data. EMR: electronic medical record.

Theme 1: System Performance (Microlevel)

The CAF defines the dimension, *system quality*, as the reliability of the system's performance, features, and security and is estimated in terms of performance and reliability, based on the system's response times for standardized tasks, integration with workflow, user-friendliness, and security [16].

Several participants explained that the quick response time for standardized tasks was a system performance factor that facilitated their use of advanced EMR features: "when I receive an abnormal test result I get it right away and I don't need to wait for the next day" (P2, age 61-70 years).

However, 2 participants mentioned that the drug database feature was not user friendly. Owing to the limitations of this feature, participants used mobile or web-based drug database applications that were not part of the EMR software as they had an easier interface and quicker response time:

> *It's so confusing…but I can write the same thing in my app…it's just easier to read and it's quicker.* [P4, age 41-50 years]

Participants also described system reliability as a barrier to using advanced EMR features (eg, EMR feature not working).

Theme 2: Completeness of Information (Microlevel)

The dimension *information quality* is defined as the completeness and accuracy of information in addition to the timeliness and relevance of information [16]. Another facilitating factor is the completeness and relevance of information provided by the EMR drug database feature:

> *the system is more sophisticated than the last time…it will show me the various dosage forms…that are available*. [P1, age 51-60 years]

A few participants were concerned about the completeness and relevance of information provided by the EMR graph feature. These limited their ability to plot and view the trend of a patient's test results:

> *It's a terrible graph…because it's not temporally organized…so it's useless as a graph*. (P3, age 61-70 years)

Theme 3: User Training and Technical Support (Microlevel)

The dimension *service quality* is defined as user training and ongoing technical support and availability of support [16]. Participants were asked if they had an IT specialist on-site to support the EMR system. A total of 6 participants raised the issue of vendors' insufficient ongoing technical support to enhance clinic performance, limited ongoing training for advanced EMR use, and ineffective user training. Technical support was not available on-site unless it was paid out of pocket or if a staff member communicated with the vendor.

Theme 4: Perceived Usefulness of Electronic Medical Record Features, Perceived Impact on Productivity, and Perceived Impact on Quality of Care (Microlevel)

The CAF cites *user satisfaction* as one category that measures the dimension *satisfaction*, defined as the subjective opinions of users with regard to their perceived expectations; value; information, system, and service quality; and use of the system. Lau et al [16] assessed the framework's user satisfaction component using indicators of perceived usefulness and value of the system, perceived impact on productivity and integration with workflow, and perceived impact on quality of care [16].

According to several participants, certain EMR features (eg, recall system and diabetic flow sheets) were useful and improved their quality of care, for example:

> *if there's a drug recall, you can find all the patients who are on that drug and call…them to come in. So it's amazing what you could do which you couldn't do on a paper chart.* [P4, age 41-50 years]

Overall, 2 participants stated that using the EMR feature to assess cardiovascular risk was time consuming and inefficient, thus impacting productivity and preventing them from using this advanced ready-made feature. One participant described the use of the cardiovascular risk feature as challenging, in that it was not fully integrated into their EMR system, necessitating the use of other online tools to calculate risk:

> *Anything that's inefficient is dangerous because it creates a barrier for people to do it. It promotes transcription errors. You move the data manually, you're going to type a key wrong.* [P6, age 51-60 years]

Theme 5: Change in Provider Efficiency, Net Cost, and Care Quality (Microlevel)

The CAF portrays *net benefits* as quality, access, and productivity. The framework assesses quality using indicators such as changes in provider effectiveness and appropriateness of care, whereas productivity is measured by indicators of change in provider efficiency, such as the time needed to assess a patient and clinician workflow [16]. The framework also refers to productivity as the change in net costs in terms of cost savings [16].

Participants reported improved workflow efficiency and improved patient efficiency when certain advanced EMR features were used. One participant described how workflow efficiency and patient efficiency were enhanced when they used a customized referral letter template to expedite a specialist referral: “So when I see an abnormal result I can send a referral at that time and its more efficient for me” [P2, age 61-70 years].

Overall, 2 participants suggested that change in productivity was a barrier to their use of advanced EMR features because of the additional cost associated with the EMR system, particularly maintaining, supporting, and upgrading the system to ensure effectiveness and efficiency. Other associated costs included after-sales support from vendors and hiring additional staff to deal with paper documents that were not electronically deposited into the EMR:

> *Since the EMR, we had to hire one person whose job was just to scan stuff in before the e-fax came.…I’m paying someone a full-time job just to scan, which is out of my pocket, which is created because of this technology.* [P4, age 41-50 years]

Furthermore, the quality of provider effectiveness and appropriateness of care were adversely affected when participants could not access patients’ test results from hospitals, in the EMR system. Participants mentioned wasting time searching for unavailable laboratory results instead of using that time for other tasks.

Theme 6: Roles and Personal Characteristics (Mesolevel)

The CAF defines the dimension *people* as the individuals or groups involved, their personal characteristics and expectations, and their roles and responsibilities vis-à-vis the HIS [17].

The framework uses an individual's age, gender, experience, and position (eg, being an IT leader) to measure personal characteristics and roles [17]. One participant with over 10 years of EMR experience, who was also the IT leader, described how they exploited the system:

> *I am too far into using EMRs.…I just do what EMR permits.…I really exploit the system.* [P1, age 51-60 years]

On the contrary, another participant (P2) with 3 years of experience using an EMR system revealed that they train their patients to remember when to do blood tests rather than use the reminder feature to prompt the physician for patient preventive services. Clearly, the participants' characteristics and roles impacted their use of advanced EMR features.

Theme 7: Return on Value and Infrastructure (Mesolevel)

The CAF categorizes *organization* as how the HIS fits with the organization's strategy, culture, and structure or processes, as well as information, infrastructure, and return on value [17]. The framework defines return on value of HIS adoption in terms of cost benefit and effectiveness. Infrastructure is measured in terms of technical architectures, level of integration, and the privacy or security in place or planned [17].

Only a few participants stated that the return on value of advanced EMR features was a barrier to the use of these features. One participant said that the electronic fax feature was expensive and not reliable, so their clinic continued to use a paper-based process:

> *And that's a problem with the software. They have an Internet faxing version, but they charge a fortune for it…and it has problems with capacity and reliability.* [P6, age 51-60 years]

Most participants noted that their inability to directly transfer documents among the EMR system and hospitals and pharmacies was a barrier. The majority of participants reported that they received laboratory results directly into their EMR system from private laboratories. However, most hospital results are faxed, scanned, and added to the patient's chart, which was another barrier. The OLIS feature facilitates searching for missing laboratory results. However, some participants mentioned that not all hospital laboratory results were available in OLIS. If they were, the amount of paper that clinics received from hospitals would decrease:

> *If I go to [the patient's] chart, I will see if their lab results are actually available through the EMR's access to OLIS….If I can do that, then I don't need all that printed paper.* [P3, age 61-70 years]

Theme 8: Governance and Privacy Laws (Macrolevel)

Some participants were concerned about the lack of leadership in addressing poor EMR infrastructure, namely, lack of direct links with hospitals and pharmacies. According to one participant:

> *the fact that we can't get stuff from hospital…There's no technical problem. There's no leadership that puts together the infrastructure and secures it to do it the way it's supposed to be done. That's all we're missing, leadership…the government can fix two things. One, they could tell the people who supply the software whom they certify, that they have to provide turnkey end-to-end service. And number two, the government actually can help create the connectivity between us and the pharmacies, us and the hospitals.* [P6, age 51-60 years]

Furthermore, 2 participants were concerned about the security and privacy of patient charts because of legislation allowing the Ontario government to access patient data.

Theme 9: Funding (Macrolevel)

A total of 2 other participants noted that they did not receive enough government funding to cover all the EMR system expenses. As one participant said:

> *[the program] didn't cover everything but it was great, but then they stopped that…then this ongoing and maintaining, it's all out of our pockets.* [P4, age 41-50 years]

Theme 10: Maturity of Electronic Medical Record Use

Participants were directly asked how their use of EMRs for performing clinical tasks had evolved since adoption. The CAF does not have a category to account for the different maturity stages of the user, so a new category was developed. The CAF describes factors that impact the success of EMR adoption at a moment in time, whereas the new theme describes how these factors evolve over time.

Overall, 2 participants stated that their use of EMRs for performing clinical tasks had not evolved effectively since adoption. They noted flaws such as technical errors with the laboratory requisition feature; poor feature design for prescribing medication doses; and excessive scanner use because of the inability to electronically transfer documents among the EMR and some hospitals and pharmacies, which was needed to support continuity of care over time. Such flaws limited these participants from using the system to its maximum capacity. As one participant explained:

> *There's way too much paper handling. Why is a person sitting at a scanner all day long? Why are we still waiting?* [P6, age 51-60 years]

However, most participants agreed that their use of the EMR system to perform clinical tasks had improved since its adoption. Several participants revealed the importance of using certain advanced EMR features (eg, electronic fax and Hospital Report Manager) to facilitate patient care delivery and reduce paper work. As one participant said, "We get features that now allow us to run almost a paperless office that did not exist when we first started" (P5, age 30-40 years). As such, the use of advanced features to facilitate patient care delivery and reduce paper work demonstrates that these physicians' use of the EMR system is maturing as they are able to incorporate advanced EMR features into their workflow.

Furthermore, using the electronic fax and Hospital Report Manager is considered advanced EMR use as physicians have incorporated these features into their clinical process as a way to facilitate CDPM. These features allow physicians to electronically access patient's results and limit the need to scan paper documents into the EMR, thereby reducing the wait time of physicians accessing patient's results. Thus, these features can improve patient care by decreasing the wait time during an appointment as the physician searches for the patient's results or the possibility of human error when scanning paper documents into the EMR, such as support staff mismatching scanned results to a patient's chart.

Theme 10 shows the need to have a temporal dimension to EMR evaluation to see what types of emerging issues will arise over time. The CAF looks at a more generic set of adoption factors, whereas theme 10 highlights the need to identify specific factors that facilitate EMR use that will emerge over time.

Discussion

This study explores primary care physicians' use of EMR systems to support CDPM. Most participants highlighted factors that facilitated their use of advanced EMR features. However, participants continue to experience barriers.

Principal Findings and Comparison With Prior Work

Microlevel Factors

Most participants mentioned that system quality and information quality factors, such as quick response time for standardized tasks (eg, receiving blood test results), and the feature's provision of complete and relevant information facilitated their use of advanced EMR features. However, participants reported unreliability as a barrier (eg, EMR feature not working), and a few participants also found the drug database feature to be non–user friendly.

Studies have recommended involving users in system design to address such technical factors [2,31,33]. As suggested in one study, professional associations, such as OntarioMD, could influence vendors by imposing standards and publishing specifications so that EMR features would be designed to benefit physicians [5].

Several participants noted that insufficient technical support and inadequate user training on the part of the vendor was a barrier. In addition, lack of on-site technical support from the vendor created additional costs such as hiring staff to address technical issues. A program such as QIDSS [13] could help address this barrier by helping physicians make better use of EMR data to improve clinical performance.

User satisfaction emerged from the data in terms of participants' perceived usefulness of an EMR feature as well as its perceived impact on both productivity and quality of care. Although several participants noted that EMR features (eg, recall system and diabetic flow sheets) supported their quality of patient care, for others, certain EMR features (eg, data entry and

cardiovascular risk feature) were inefficient and time consuming, thus a barrier to their productivity.

A systematic review recommended discussing the usefulness of a given EMR feature, demonstrating its ease of use, and having fellow physicians demonstrate the feature [34]. OntarioMD's Peer Leader program is a network of clinicians with several years of EMR experience. These individuals support practices in Ontario to advance their EMR use [35]. Such a program can help address the user satisfaction barriers identified in our study.

Mesolevel Factors

According to our findings, participants who were IT leaders and had more EMR experience were more likely than others to exploit the EMR system. These findings are consistent with the diffusion of innovations theory, which describes how characteristics of potential adopters (eg, expertise and perception of innovation) influence the success of innovation adoption [10]. Furthermore, a commonly cited infrastructure barrier was the inability to directly transfer documents among the EMR system and hospitals and pharmacies. This barrier has also been identified in other studies [5,36].

Macrolevel Factors

Lack of leadership in addressing poor interoperability among EMR systems and hospitals and pharmacies is an important macrolevel factor discussed by a few participants. A grounded theory study conducted in Ontario also noted the lack of connectivity among clinical EMRs and hospital laboratories [5]. The study recommended that OntarioMD could influence software development via standards and publishing future requirements and through financial support to improve the interoperability among EMR systems and other health care entities [5].

Legislation and funding also emerged as issues in the data. Some participants were uneasy regarding the security and privacy of patient charts because of legislation that allows the Ontario

government to access patient data. Other studies have also shown that concerns about privacy and security of patient data are a barrier to EMR use because of the potential legal problems [34,37,38].

In addition, participants who were not part of an FHT practice felt that government funding was not sufficient to cover EMR expenses. These findings confirm those of other studies in which barriers related to insufficient funding influenced the adoption and use of EMRs [2,5,39].

Maturity of Electronic Medical Record Use

Most participants thought that their use of EMR systems had improved since adoption with the support of advanced EMR features (eg, electronic fax and Hospital Report Manager). Studies that assessed clinicians' use of EMR systems found that longer EMR use led to improved outcomes (eg, greater expertise and improved patient care) [14,15]. Some of the key factors explored in this study could be measured over time to assess the different maturity stages of physicians' use of advanced EMR features.

Key factors such as reliability, functionality, and user-friendliness of the EMR feature; technical support and user training; user satisfaction; productivity; return on value; and infrastructure, could be assessed as part of the mature use of an EMR system either quantitatively using surveys or qualitatively through interviews. One possible method would be ranking the progress of each key factor for each advanced feature and the progress of mature use of these advance features. For example, for the advanced feature OLIS, its reliability, functionality, and user-friendliness could be ranked using a Likert scale that ranges from 0 to 5, where 0 indicates that the user strongly disagrees that OLIS is reliable, functional, and user friendly. Similarly, the progress of mature use can be assessed using a 5-point Likert scale, where 0 shows that the user strongly disagrees that the feature is fully integrated within their clinical workflow (eg, feature is not being used) and 5 implies that the user strongly agrees that the feature is fully integrated within

their clinical workflow (eg, feature is used to access patient's current and past test results to enable treatment decisions and, if applicable, results are shared with the patient at the point of care). A longitudinal analysis of a clinic would need to be done to measure the progress of these key factors over time and the progress of mature use of these advanced EMR features. Thus, the maturity of EMR use dimension extends the CAF by incorporating postadoption factors perceived by physicians to influence their use of advanced features and the effects of these factors over time to reflect the different maturity stages of the user.

An application of this extended CAF would be to evaluate the progress of advanced EMR feature use among primary care physicians. Another would be for physicians to identify potential factors within their practice that influence their use of advanced EMR features in reaching maturity and to make recommendations for improvements.

Furthermore, the extended CAF could be used by key stakeholders, such as Canada Health Infoway and OntarioMD, to assess the progress of advanced EMR feature use to inform future policies designed to sustain the momentum of advanced EMR feature use.

Limitations and Strengths

One limitation of our study is the composition of the participant sample. OntarioMD assisted with recruiting participants by reaching out only to its peer leaders. Peer leaders are typically super users who could be biased favorably toward EMRs. Another limitation is that no participants were located in a rural setting. This group might report other barriers or motives. Researcher bias because of using directed content analysis is another limitation, as researchers are likely to find evidence supportive of their theory. Finally, participants might have answered questions a certain way to please the researcher [24]. Doing an audit trail minimized biased results.

In addition, as the type of EMR software investigated was dependent on the software used by participants, the study only involved 3 types of EMR software: PS Suite, IndiviCare, and Nightingale On Demand. This may have prevented us from observing other advanced EMR features available in other EMR software. Moreover, the EMR software we investigated were all OntarioMD certified, which provided additional benefits (eg, access to Hospital Report Manager, OLIS, and EMR funding eligibility). Other factors might have emerged had we investigated non–OntarioMD-certified EMR systems.

A key strength of this study is that physicians were interviewed in person, providing a deeper understanding of their responses and allowing them to demonstrate certain EMR features. This, in turn, allowed us to observe the barriers and facilitating factors experienced by participants. In addition, the credibility of this study was enhanced by coauthors auditing the results and 2 team members independently analyzing transcripts.

Conclusions

In this study, 9 primary care physicians in Ontario discussed barriers and facilitating factors that influenced their use of advanced EMR features. This study also extended the CAF through the emergence of a new dimension regarding the maturity of users' EMR use. The extended CAF can be used to support key stakeholders in tracking the use of advanced EMR features, which would support future policies. A future research direction could be the development tools (eg, survey or interview guide) to formally evaluate the extended CAF. Overall, our findings show that although primary care physicians' use of EMR systems has improved, barriers remain and need to be addressed to further enhance the physicians' use of advanced EMR features to facilitate CDPM.

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Authors' Contributions

RR, the primary investigator, conceived, led, and coordinated the development and writing of the manuscript; RR and SY independently analyzed the transcripts; SY participated throughout the development and writing of the manuscript; RR, SY, and CK audited the data analysis findings; and SY, CK, and JM reviewed and made substantial contributions to the manuscript, contributing intellectual content and feedback on the drafts of the paper. All authors read and approved the final paper.

Conflicts of Interest
None declared.

Multimedia Appendix

Multimedia Appendix 1. Electronic medical record maturity model.

Multimedia Appendix 2. Clinical adoption framework.

Multimedia Appendix 3. Interview Guide.

Abbreviations
CAF: Clinical Adoption Framework

CDPM: chronic disease prevention and management

EMR: electronic medical record

FHT: family health team

HIS: health information system
IT: information technology
OLIS: Ontario Laboratories Information System
QIDSS: quality improvement decision support specialist

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Chapter Six. Process Improvement for the Management of Laboratory Results Using Electronic Medical Records in a Primary Care Setting

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Abstract

Background: The use of electronic medical records (EMR), specifically certain EMR features, has been shown to facilitate patient uptake of preventive services and improve patients' quality of care. Although the rate of EMR adoption has increased, recent studies have shown that there is a large variation in the use of EMRs among different types of primary care practices. While there is evidence supporting the benefit of EMRs in chronic disease prevention and management, little is known about how EMRs and their features, such as laboratory results management (the focus of this paper), are used to support chronic disease prevention and management.

Objective: To understand how EMRs and their features are integrated in primary care physicians' workflows, in order to assist in optimizing chronic disease prevention and management processes and support the delivery of care for patients living with chronic diseases.

Methods: A qualitative method is used to explore primary care physicians' workflow in order to uncover how EMR features, specifically those designed for laboratory results management, are used to facilitate chronic disease prevention and management. Direct observations of nine primary care physicians captured the ways in which EMR features are integrated in primary care physicians' processes. Process mapping was used to develop and visualize the current state of physicians' processes in order to identify waste conditions that disrupt the process flow and to streamline current-state processes. This will help in recommending a future-state process.

Results: Six improvement strategies are recommended to enhance primary care physicians' current-state processes of laboratory results management using EMRs: (1) that physician analyze patients' laboratory results prior to meeting them, (2) that laboratory results are available on the patient's chart prior to the patient's appointment, (3) that physicians and support staff receive on-going training so that they are aware of the interfaces of new laboratory repositories, (4) that a checklist or a software tool is used to reduce the mismatch rate of laboratory results to a patient's chart, (5) that an adequate physician-to-staff ratio is maintained to minimize backlog, and (6) that a mechanism (e.g., EMR reminder feature or a software tool) be used to track patients' laboratory results in the EMR.

Conclusion: Identifying workflow patterns that create waste within processes is crucial to the long-term success of laboratory results management, which in turn will facilitate chronic disease prevention and management. By applying qualitative methods, an in-depth understanding of optimizing laboratory results management processes was developed.

Keywords: electronic health records; chronic disease; primary health care; medical informatics

6.1 Introduction

6.1.1 Background

Chronic diseases are accelerating globally, and the number of deaths due to them has increased worldwide [1]. Electronic medical records (EMRs) is one strategy used to manage chronic diseases by facilitating their early detection [2, 3], for example, displaying disease status trends and tracking patient compliance with recommended care guidelines [4, 5].

The rate of EMR adoption is increasing internationally [6]. However, this does not necessarily mean that systems are being used to their full potential. A Commonwealth Fund study showed that Canadian practices with five or more full-time equivalent physicians were significantly more likely to use EMRs than practices with fewer than two full-time physicians. Moreover, larger practices were also more likely to use at least two EMR features [6]. Another Canadian study showed that primary care practices based on a collaborative model (e.g., interprofessional teams and the use capitation payments) were more likely to use EMRs than traditional practices (e.g., solo and those that use fee-for-service payment) [7]. Thus, there is a gap in our understanding of how EMRs are being used by primary care practices to support primary care delivery, specifically for chronic disease prevention and management.

6.1.2 Advantages of EMRs

Several researchers have noted that certain EMR features facilitate chronic disease prevention and management. A cluster randomized controlled trial study found that electronic reminders, a feature that is used for systematic preventive patient care, were associated with an increased uptake of colorectal cancer screening in patients from primary care practices [8]. Another study determined that the practices whose EMRs had a reminder feature for screening tests were associated with improved quality of care (e.g., lower odds of receiving inappropriate urinalysis) [9]. Typically, reminder features are designed to provide patient preventive services. In Ontario, a province in Canada, in some EMR software such as IndiviCare, the reminder feature is made up of two functions—one for patient preventive services and the other (known as "Ticklers") to keep track of tasks [10]. Other EMR software used in Ontario, such as Practical Solutions by TELUS, enables users to either send a "message to self" or add a special note to the patient's chart to remind the user of upcoming tasks [11].

Moreover, EMR features such as direct links to laboratory and radiology services support physicians' laboratory work processes by allowing orders to be completed directly in the EMR and for the results to be automatically uploaded into the system, thereby promoting efficiency by reducing test duplication and delays in obtaining results [12]. In addition, EMR features with connectivity to private labs receive results more quickly, and less time is required to find results and match them to the patient's chart [12]. Several EMR systems have a feature known as the lab

inbox that automatically receives electronic laboratory test results directly from private laboratories and also allows for paper results to be scanned in by support staff [10, 11]. In Ontario, a new laboratory repository known as Ontario Laboratory Information System (OLIS) promotes a seamless link between hospital laboratories and EMRs [13]. Other common EMR features that support the delivery of care for patients with chronic diseases include the graph feature (e.g., graphing patient's lab result values) and the schedule feature (i.e, one of the gateways to access a patient's chart and view a patient's lab test results) [11, 14].

6.1.3 Process Improvement Strategies

Much previous research has evaluated new workflow-related challenges introduced by health information systems [15–17], and typically health care providers cite the impact of health information systems on workflow as a potential barrier to implementation [18–20]. Health information systems that are poorly aligned with clinicians' workflow can lead to their rejection of the system or produce unexpected negative outcomes [21, 22]. Several studies have analyzed the impact of health information systems, such as EMRs, on clinical workflow [16, 23–27]. One study applied a time-motion quantitative approach to collect data about workflow, using a structured electronic data collection instrument to quantify the workflow [25]. Other studies have applied a qualitative approach to analyze clinical workflow through direct observations, semi-structured interviews, and documentation analysis [16, 23, 24, 27]. Yet another study used a mixed methods approach, combining a time-motion analysis with direct observations and

interviews [26]. A systematic review that explored methods used to study and model workflow found that there was no standardized approach for studying workflow and that methods ranged from ethnographic observations to usability techniques, where ethnographic observation and interviews were the most frequently used methods [28]. This study also applies empirical methods such as observations and interviews.

Studying the interaction between workflow and technology has been done in fields other than healthcare. In the 1900s, researchers applied quality improvement methods based on engineering and management concepts to study workflow and efficiency in manufacturing settings [29–31]. Lean methods, one of the most widely used quality improvement strategies, originated with Toyota in the automotive industry but have been used extensively in health care settings [32–34]. Lean methods use process mapping as a tool to identify the specific activities in a process. With lean methods, both the current state of the process and a desired future state are mapped. Lean principles seek to improve process flow by eliminating waste conditions (such as activities that do not add value), standardizing work, removing disruptions (e.g., errors) from the current process, and recommending future improvements to streamline the current-state process and reach a future-state process [35].

6.1.4 Objective

From the studies reviewed for this article, it is apparent that EMR features promote improved quality of patient care. Unfortunately, the use of EMRs to their fullest potential is not

evident across primary care practices [7]. Researchers have found that when health information systems are implemented, their features may initially be used in a limited manner, with an increasing degree of process automation occurring over time [36, 37]. Exploring primary care physicians' workflow processes when they use EMRs for chronic disease prevention and management can help understand how clinicians use EMRs to better adapt them into their workflow and improve the quality of care for patients living with chronic diseases.

Chronic disease prevention and management is complex and dynamic and involves many processes. This study focused on one key area within chronic disease prevention and management, namely, the management of laboratory results. To address the research objective of streamlining primary care physicians' laboratory results management using EMRs, our study applied a qualitative approach in conjunction with lean methods. We aimed to recommend the best common practice for physicians' laboratory results management using EMRs.

6.2 Methods

6.2.1 Study Design

Guided by lean principles, this study employed a qualitative approach to map how EMRs and their features are integrated in primary care physicians' work processes to support laboratory results management. To provide a rich description of the workflow, qualitative data were collected through direct observations of primary care physicians using their EMRs to support

laboratory results management. Paper-based field notes were taken to identify the people, data, and objects involved in the work process. Following this observation, open-ended questions directed to the primary care physician were used to verify the observations and seek explanations for discrepancies in the data.

For this study, the data were then used to develop a current-state process map for each participant to explore how they integrated EMRs and their features into their laboratory results management. The current-state process maps for each participant were then combined into one comprehensive current-state process map that included the processes that were common among the participants.

The individual and comprehensive current-state process maps were also validated with participants, which added to the validity of our study [38]. The process maps were created in an iterative manner and member checked: participants were involved in the initial review and subsequent reviews of the current-state process maps until a consensus was reached that the process had been correctly and completely mapped. This technique was also used in a systematic review of several workflow studies that reviewed and verified findings with the study subjects to evaluate the quality of the study results [28].

The comprehensive current-state process map was useful for exploring where improvements could be made to the physicians' work processes and for developing a future-state process map that streamlined the current-state process.

6.2.2 Setting

The recruitment for this study targeted family physicians in the cities of Ottawa, Toronto, and Hamilton, all located in the province of Ontario. The study population included participants from all models of primary care practice in Ontario (family health team, community health center, independent practice, and the Rural-Northern Physician Group Agreement). All non-general practices were excluded from the study, as were physicians who did not use EMRs in their practice. Patients were also excluded, as the focus was on the processes used by primary care physicians in their clinics.

6.2.3 Participants and Sampling

Purposeful sampling was used to represent participants of a range of ages, of both sexes, and from all three cities. The stakeholders, OntarioMD (responsible for certifying EMRs in Ontario [39]) and the Ottawa Hospital Family Health Team [40], assisted in recruitment by sharing an advertisement for this study with their members. Additionally, recruitment emails were sent out to individual family practices. Participants who expressed interest reached out to the primary author (RR), from whom they received a copy of the consent forms. The participants included family physicians, both male and female, between the ages of 30 and 70.

6.2.4 Data Collection

Data collection and analysis occurred from January to July 2017 through direct observations, informal interviews to clarify observations, and the development of workflow models (see Figure 6.1). Data collection and analysis continued until data saturation, i.e., when additional data did not substantially change the analytical results [41]. Data saturation was achieved with nine primary care physician participants. A previous systematic review of several workflow studies used the data saturation technique to ensure the quality of the study results [28].

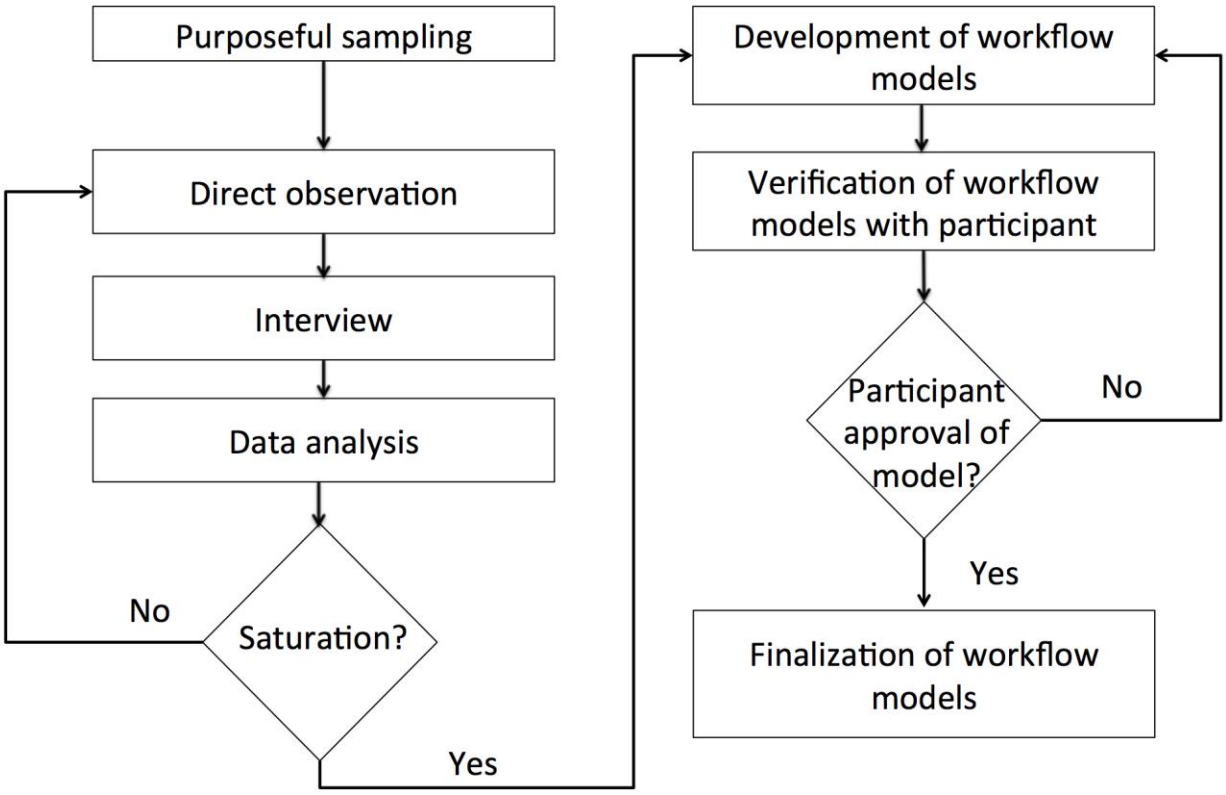

Figure 6. 1 Study design.

6.2.5 Observational Tool

Field notes were used to collect the data necessary to develop the process maps indicating how EMR features were integrated into primary care physicians' laboratory work processes. Direct observations of primary care physicians provided a way to purposively seek specific information about their work processes and the technology and people they interacted with. Traditionally, paper-based data collection methods have been used in direct observations of workflows [28, 42, 43], while other studies have used electronic-based observational tools in direct observational studies of health professionals [24, 44, 45]. In this study, two kinds of paper-based field notes were created, namely, notes with descriptive information to document factual data and notes with reflective information to record ideas and questions generated during the observations.

Primary care physicians were observed at their workplaces. Observations were performed either in the physician's office or during an appointment in the exam room (the latter with the patient's consent). Observations did not take place after clinical hours. The duration of observations varied from participant to participant and based on the physician's availability. Observations ranged from 3 to 5 hours.

During the observations in the exam room with the patient, the observer (the primary author [RR]) was not able to see the patient's profile on the physician's computer screen.

Instead, participants stated which EMR features they were using. In human factors engineering, this "thinking-aloud" approach has proven to be a useful technique in collecting workflow data [35]. In addition, to avoid making the patient feel uncomfortable, the observer sat on a chair in the exam room, rather than standing, while taking notes. After the observation period, the observer asked the participant open-ended questions to verify the observations and seek explanations for discrepancies in the data.

6.2.6 Ethical Considerations

This study has been granted ethics approval from the University of Ottawa Research Ethics Board (H01-16-02). After a verbal briefing about the purpose and structure of the study, participants signed a consent form. No personal information was recorded and participants' names were codified such that their identities were not revealed. Patients also provided written consent to allow the primary author (RR) to conduct observations in the exam room.

6.2.7 Data Analysis

Process mapping

Lean methods involve the use of process mapping as a tool to visualize workflows [46]. Process maps were based only on observations of the user of the EMR (i.e., the physician); the actions of the patients were not considered. Thus, only one actor was involved in the process. The goal of the lean approach is to eliminate waste and improve flow [47]. The more waste that

is eliminated, the more efficient the process will be [47]. Process mapping revealed waste in how primary care physicians in Ontario are currently using EMRs and their features to support laboratory test results management.

Lean methods are used to identify eight common categories of waste, which can in turn indicate process deficiencies: (1) overproduction (e.g., more production than is needed or production before it is needed), (2) waiting (e.g., wasted time waiting for the next step in the process), (3) unnecessary transportation (e.g., the unnecessary movement of products or materials), (4) overprocessing (e.g., more work or higher-quality being done than is necessary), (5) inventories (e.g., a backlog of work), (6) unnecessary movement (e.g., people's performance of unnecessary steps), (7) production of defective parts (e.g., data errors, missing information), and (8) underused employee abilities or creativity [47].

Process mapping illustrates the relationships between the activities, people, data, and objects involved in the production of a specific output. It also shows where improvements can be made [48]. To facilitate this study, we used flowcharts to visually represent the work processes of primary care providers. Flowcharts illustrate the sequence of the performer's work activities to create, produce, or provide a single specific output [48].

To map the work processes, variables such as input, output, objects, and people were manually determined from the primary data collected during observations. A current-state process map was constructed for each participant. Additionally, specific symbols were used in

the development of the process maps: oval (start or end point), arrow (relationships between shapes), rectangle (a process), and diamond (a decision node). Process mapping was used to examine PCP's clinical workflow for laboratory results management while using an EMR.. Analysis of the observation and interview data guided the model development. We identified sequences of routine activities related to laboratory results management, such as the type of EMR feature used and when features were accessed in the process.

6.3 Results

6.3.1 Participant Characteristics

Table 6.1 summarizes the sample and participant characteristics. Participants' experience using an EMR system ranged from 3 to 15 years. Five of the participants were part of a group practice using the family health organization (FHO) capitated payment model, three were from a family health team (FHT) practice model, and one was from an independent practice. Four of the participants used the EMR system PS Suite, three used IndiviCare, and one worked with Nightingale On Demand.

Table 6. 1 Participant characteristics.

Participants	Age range	Sex	Primary care model	Years of experience using EMRs
P1	51–60	M	FHT	15

P2	61–70	F	Independent practice	3
P3	61–70	M	FHT	10
P4	41–50	F	FHO	7
P5	30–40	M	FHO	7
P6	51–60	M	FHO	15
P7	30–40	F	FHT	4
P8	41–50	M	FHO	4
P9	61–70	F	FHO	9

The primary author (RR) conducted a total of 34 hours of direct observation with the nine primary care physicians, entailing 52 EMR–physician interactions. Individual process maps were developed for each provider observed, thus a total of nine process maps were created. Individual current-state process maps were created based on the observer's (RR) paper-based field notes generated during observations and during the question period with the physicians to clarify observation discrepancies.

6.3.2 Current-State Process Maps

During data analysis, the nine current-state process maps were compared for similarities and differences in workflow, information flow, and EMR features that the physician used, in order to develop one comprehensive current-state process map. The Pareto principle (i.e., 80/20 rule) [47] was applied to prioritize the processes that were common among the nine participants

and therefore included in the comprehensive current-state process map. The Pareto principle is commonly used in lean management when developing process maps, and it predicts that 80% of results are obtained from 20% of the known variables [49]. Thus, the comprehensive current-state process map included processes that were common to at least 20% of the participants, since the Pareto principle assumes that 20% of the participants' actions will account for 80% of the outcomes.

The comprehensive current-state process map and their individual current-state process map were sent to all of the participants for their review and feedback. The comprehensive current-state process map comprises three components: laboratory results management prior to patient's visit, batch laboratory results management prior to patient's visit, and laboratory results management during patient's visit. Figures 6.2, 6.3 and 6.4 show the common workflow patterns of these three processes. Detailed workflow patterns of the current-state process maps, which also present the waste conditions (shown as red bubbles), can be found in Appendix G.

Laboratory results management prior to patient's visit

Figure 6.2 shows the common workflow tasks related to laboratory work that are performed by primary care physicians. These steps are carried out in the physician's office prior to the patient's visit to prepare the physicians for the appointment. For all nine physicians observed, the process began with the physician logging into the EMR software. Most physicians accessed the schedule feature in the EMR software to view upcoming appointments. At this

point, the processes among participants varied depending on the physician's appointment schedule. Participants who did not have an immediate appointment scheduled, that is, within the next few minutes, accessed the laboratory inbox feature to review a batch of recently received laboratory results. The process then continued to the second component, 'Batch laboratory result analysis' (see Figure 6.2).

Of the physicians who had an immediate appointment scheduled, roughly one-third did not look for the patient's laboratory results prior to the patient's appointment but created a reminder (e.g., left a note on patient's file, sent a message to self, or used the Tickler feature) to go through laboratory results with the patient during the appointment. The other participants who had immediate appointments scheduled accessed patients' charts to review their laboratory results and read messages tied to the patients' charts. Messages not related to laboratory results were considered out of scope and were not captured in the process. For messages related to laboratory results, participants had multiple sources from which to access the patients' results in order to prepare for their appointment (see Appendix G for detailed workflow patterns).

The sources from which results could be retrieved were the patient's chart, laboratory inbox, OLIS, paper file, and support staff. If participants could not access the patient's laboratory results from the patient's chart, laboratory inbox, OLIS, or from the paper file, support staff were asked to access the results, scan and append them to the patient's chart. Once they had the results, participants determined whether the results were normal or abnormal. For normal results,

the majority of participants signed off the laboratory results and archived the message. With abnormal results, the process varied among participants. Roughly one-third analyzed the laboratory results and observed trends in blood work using the graph feature; the others did not. The majority of participants ended the process by viewing the patient's profile summary to understand the purpose of the patient's visit, then logged off the EMR software to go to the exam room and see the patient.

Wastes

Several waste conditions were identified in the process. First, roughly one-third of physicians observed did not review patient's laboratory results prior to the patient's visit but during the appointment. One of these physicians (P2) practiced in a fee-for-service payment clinic and the other (P3) worked in an FHT, although they had previously worked in a fee-for-service system. If the physician searches for the results during the appointment, a waste condition of wait time for the patient can result. As well, extra processing is required for the physician to find the results, which extends the duration of the patient encounter.

Second, the inaccessibility of laboratory results in the patient's chart creates a bottleneck in the process as physicians wait for results to become available. Feedback from some participants indicated that inaccessibility was usually due to a backlog in scanning paper files and attaching them to the appropriate patient chart. In most instances, the root cause of the

backlog is insufficient staff to scan results. In another scenario related to the inaccessibility of results, a few participants commented that they did not know whether or not the patient had completed the laboratory work. One participant mentioned the difficulty of adapting to the new interfaces of alternate sources and the participant also stated that some of their physician colleagues were unaware of alternate sources for accessing laboratory results (e.g., OLIS).

Third, when validating the current-state process maps with participants, a few participants raised the issue of the mismatch of laboratory results to a patient's chart. Although a rare occurrence, this leads to a defect waste with respect to human error (e.g., support staff mismatching scanned results to a patient's chart). In addition, extra processing is required for the physician to verify whether the results are matched to the appropriate patient's chart.

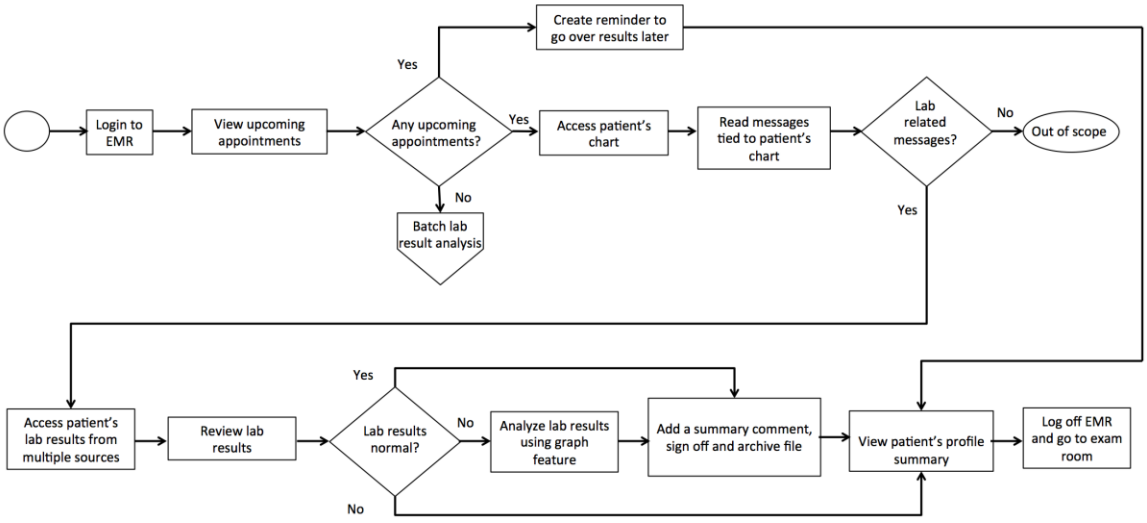

Figure 6. 2 Current-state process of laboratory results management prior to patient's visit.

Batch laboratory results management prior to patient's visit

Two out of the nine physicians observed did not have immediate appointments scheduled, so they had time to open the laboratory inbox feature to address a batch of recent laboratory patient results. The batch laboratory results management current-process map (see Figure 6.3) describes laboratory results analysis and management in the laboratory inbox feature as performed by primary care physicians. These steps were carried out prior to a patient's visit in the physician's office when the physician did not have appointments. (For detailed workflow patterns, refer to the process map shown in Figure 2, Appendix G.)

The process began with the participant opening the laboratory inbox feature. The laboratory inbox contained either electronic files received directly from private laboratories or a PDF file. PDF files typically came from support staff scanning paper files and assigning the scanned files to the responsible physician in the laboratory inbox. The physician then reviewed the results to determine if they were normal or abnormal. For normal results, if the file came in electronically the physician added a summary comment about the laboratory results for future reference, then signed off and archived the file. If the file had been scanned, the physician double checked that the file had been attached to the correct patient's chart, and if so, the physician added a summary comment about the results, then signed off and archived the file.

If the results were abnormal, the participants analyzed the results and used the graph feature to assist in their analysis and determine the reason for the abnormal results. Once again, if the file had been scanned, the physician had to check that the file was attached to the correct patient's chart. After analyzing the abnormal results, the physician created a reminder to discuss them with the patient. Depending on the EMR software, reminders were created either by adding a note on the patient's chart, by sending a message to self or using the Tickler feature. Participants also sent an action message in the EMR to support staff (e.g., prepare laboratory requisition forms if additional tests were needed). If participants did not have an immediate appointment scheduled, they continued clearing their inbox of laboratory results.

Participants ended the process by accessing the schedule feature to view appointment room details. They then logged off the EMR software to go to the exam room to see the patient.

Wastes

Two waste conditions were identified in this process. The first, as discussed previously, was the mismatching of laboratory results to the patient's file. This occurrence, which is rare, happens when a scanned file is sent to the laboratory inbox. Support staff must manually attach scanned files to the appropriate patient's chart based on certain patient information (e.g., demographics and health card number). This process is susceptible to human error and may compromise patient safety. As well, this results in the waste condition of extra processing for the physician, who needs to verify that the results match the appropriate patient's profile.

The second waste condition is with regards to the backlog in scanning paper files and appending scanned copies of laboratory results to patients' charts. Inaccessible laboratory results is an outcome of this waste condition. As well, the backlog of unattached results creates the waste of extra processing for physicians who have to attach the file themselves. Some physicians stated that the backlog was mainly due to limited budget and staff resources. This is a high priority task (i.e., critical) for the management of laboratory results, and not keeping it up to date causes waste such as a backlog of files and wait time to receive results.

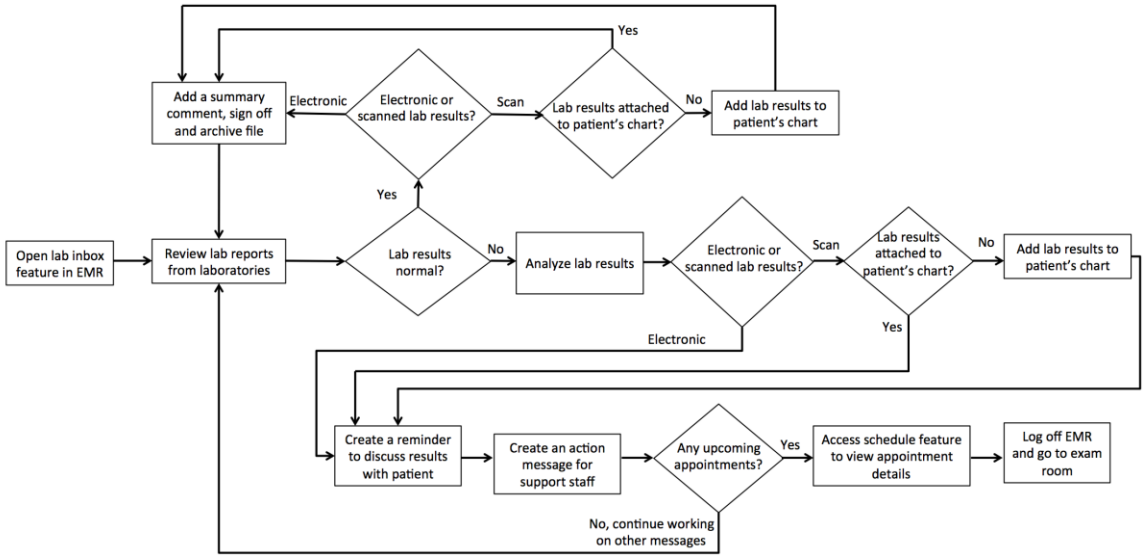

Figure 6. 3 Current-state process of batch laboratory results management prior to patient's visit.

Laboratory results management during patient visits

Figure 6.4 delineates the tasks related to laboratory work that are performed by the participants during patient encounters. (See Figure 3 in Appendix G for detailed workflow patterns.)

In the exam room, the majority of participants began by logging into the EMR software and then accessing the schedule feature to pull up the patient's chart. At the beginning of the patient encounter, the participants documented patient encounter notes in the patient's chart and then accessed the patient's laboratory results. If the laboratory results were not available in the patient's chart, the physicians turned to three sources to gain access: laboratory inbox, OLIS, or support staff. In the event of abnormal laboratory results, a third of the participants (P1, P4, P5) did not analyze the results but directly shared the results with the patient, whereas the rest of the participants analyzed the results prior to sharing the results with the patient.

After sharing the results, the majority of participants documented patient encounters and then determined whether the patient required blood tests. If the patient did, the physician filled out a laboratory requisition form in the EMR, printed the form, signed it, and gave the form to the patient. A process in variation was observed again, where one-third of participants created a reminder in the EMR to follow up with the patient to ensure that the blood work was completed. The process ended by participants accessing the schedule feature to get the details of their next appointment and then logging off the EMR.

Wastes

Four types of waste conditions were found in this process. As with the previous two processes, the wastes of inaccessible laboratory results and mismatching results with a patient's chart also applied to this process of participants accessing a patient's laboratory results. The third waste condition observed was analyzing the laboratory results during the patient encounter, which two-thirds of the participants did. Physicians confirmed that they had done this, during the question period. Analyzing results during a patient's visit leads to a waste of wait time because it increases patient encounter time. Lastly, one-third of participants created a reminder to follow up with their patient to complete laboratory work (see Figure 6.4). Although this is a useful procedure for physicians, not having a standard mechanism to track the progress of a patient's laboratory work results in a waste condition for the physician because they spend time following up on patients' blood work.

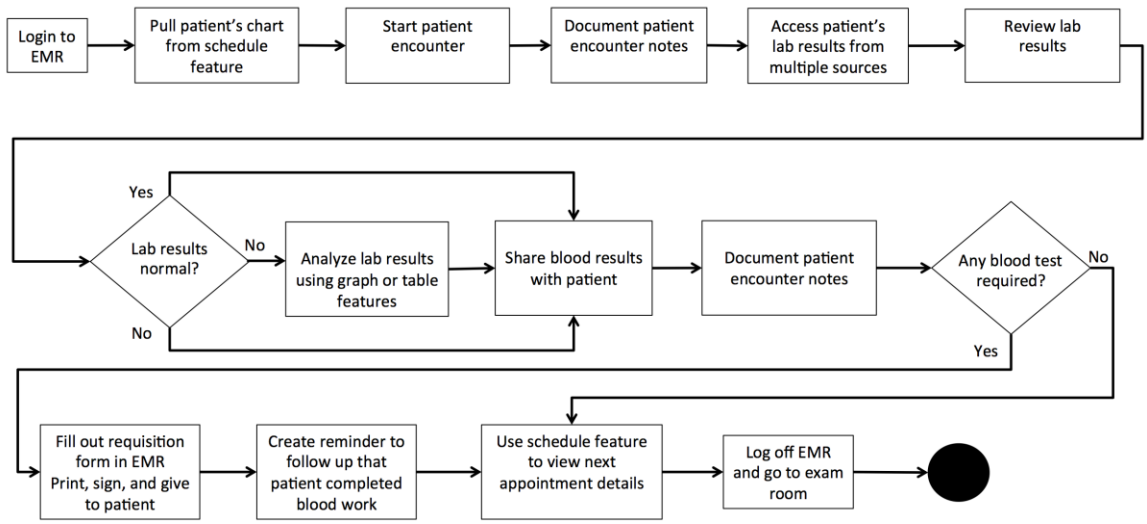

Figure 6. 4 Current-state process of laboratory results management during patient visit.

6.3.3 Future-state process map

This section recommends a best common practice for laboratory results management with the use of EMRs in a primary care setting and the future-state process maps are shown in Figures 6.5, 6.6, and 6.7. The waste conditions identified in the current-state process maps have been eliminated in the future-state process maps, and recommendations for improvement to achieve a streamlined process are provided. (See Appendix H for detailed workflow patterns of the future-state process maps along with future-state recommendations, shown as yellow stars). Table 6.2 shows the future-state recommendations for all the waste conditions identified.

Furthermore, we applied the workflow elements framework [28] to the workflow patterns in Figures 6.5, 6.6, and 6.7 to show a general approach to the future-state processes and provide readers with the necessary information for them to determine whether our findings can be generalized to their context (see Figures 6.8 and 6.9). The workflow elements framework was developed based on a systematic review of workflow literature and describes workflow at the specific level and at the pervasive level [28]. The specific level is composed of people performing actions (actors) that produce outcomes, the physical and virtual tools the actors use to enable actions (artifacts), and characteristics that describe the actions. The pervasive level is made up of three components that influence the specific-level components of workflow: context (work setting, environment, culture, social context, physical and virtual workspace), temporal

(timing of events, scheduling, coordination of events), and aggregate (the relationship and interactions between different tasks and actors, including coordination, cooperation, and conflict).

Table 6. 2 Future-state recommendations and current-state waste conditions

Current state (waste conditions)	Future state (recommendations)
1. Majority of physicians analyzed patients' lab results during patient encounters	• Physicians analyze patients' laboratory results prior to patient encounters
2. Inaccessibility of lab results in patients' files, creating a bottleneck in the process	• Lab results be available on patient's chart prior to patient's appointment (set a time interval for lab results to be available on patients' chart)
3. Inaccessibility of lab results is due to the unawareness of alternate sources to access lab results and the reluctance to learn and adapt to new interfaces	• Physicians and support staff become aware of and be trained on the interfaces of new laboratory repositories
4. Mismatching of lab results to patients' files (rare occurrence)	• Short term: add a checklist at the source when scanning results to patients' files. Also, staff make use of OLIS to minimize mismatching • Long term: have software that automatically matches scanned bulk paper file lab results to the appropriate patient file
5. Backlog in scanning of paper files and attaching scanned copies of lab results to patient's file due to limited budget and staff resources	• Maintain adequate physician-to-staff ratio to minimize backlog • Prioritize this task with staff because it is one of the critical tasks in this process • Have staff make use of OLIS to facilitate the backlog

6. No standard mechanism to track progress of patient's lab work	• Short term: implement a tracking system to monitor whether the patient has completed blood work • Provide training to enhance the use of the reminder feature to track the progress of patient blood work • Long term: implement software tool in EMR to monitor progress of lab results

Laboratory results management prior to patient's visit

A future-state recommendation for this process is for physicians to analyze patients' laboratory results prior to the patient visit (to ensure, for example, that laboratory results are matched to the appropriate patient chart).

Second, to address the waste condition of inaccessible laboratory results, in the future state, laboratory results should be available on the patient's chart prior to the patient's appointment and a time interval should be set for when results are to be available on the patient's chart. Another future-state recommendation that addresses inaccessibility is that physicians and support staff be made aware of the different sources available for accessing laboratory results (e.g., OLIS, laboratory inbox, paper file) and be trained on the interfaces of the new laboratory repositories to alleviate the barrier of learning a new system. Other future-state recommendations to address inaccessibility include implementing a tracking system to monitor whether the patient

has completed their blood work and maintaining an adequate physician-to-staff ratio to ensure timely access to results.

Finally, while mismatching laboratory results to the wrong patient's file is a rare occurrence, it is another waste condition found in the current state in this process. The future-state recommendation is to work towards reducing the mismatch rate of laboratory results to a patient's chart. A short-term recommendation is to use a checklist at the source when scanning results to a patient's file. Another short-term recommendation is for staff to use the repository OLIS, where laboratory results are already matched to a patient's chart. A long-term future-state recommendation is to have a software tool embedded in the EMR that automatically matches scanned bulk laboratory files to the appropriate patient's chart.

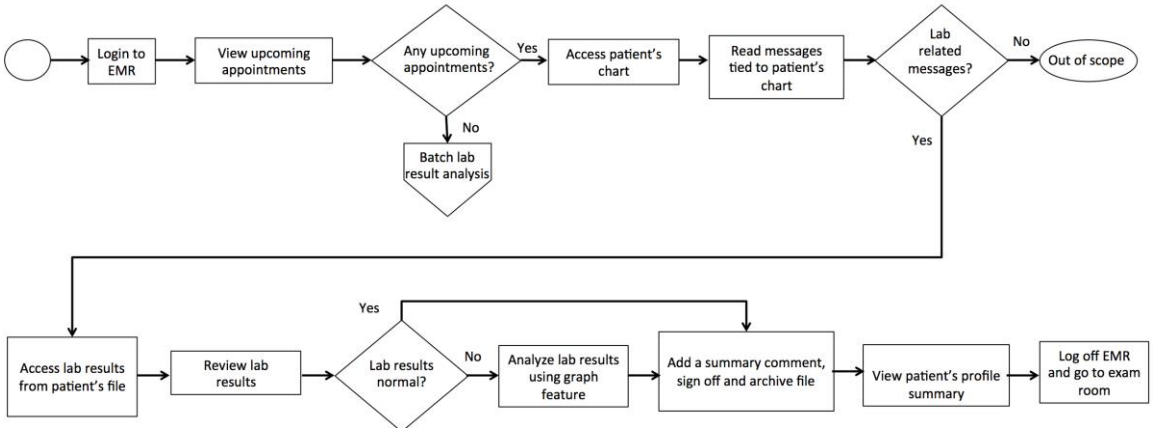

Figure 6. 5 Future-state process of laboratory results management prior to patient's visit.

Batch laboratory results management prior to patient's visit

An essential future-state recommendation for this process is to maintain an adequate physician-to-staff ratio to minimize the backlog of paper file laboratory results that need to be scanned. Scanning paper laboratory files and attaching the files to the patient's chart is a critical task in the process, and a future-state recommendation is to prioritize this task with staff accordingly. As well, it is recommended that staff make use of OLIS to eliminate the need for scanning and attaching results to a patient's chart.

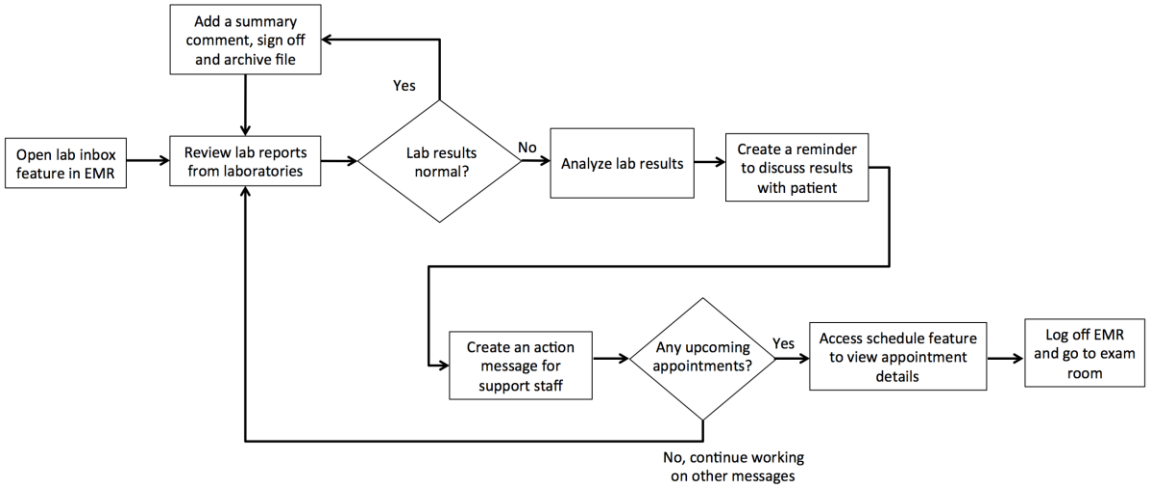

Figure 6. 6 Future-state process of batch laboratory results management prior to patient's visit.

Laboratory results management during patient's visit

A primary future-state recommendation for this process is to address the absence of a standard mechanism to track the progress of patients' laboratory work. Future-state recommendations include implementing a tracking system to monitor the progress of a patient's

blood work and training staff to use the reminder feature to track the progress of a patient's blood work more effectively. A long-term recommendation is to embed a software tool in the EMR that monitors the progress of laboratory results.

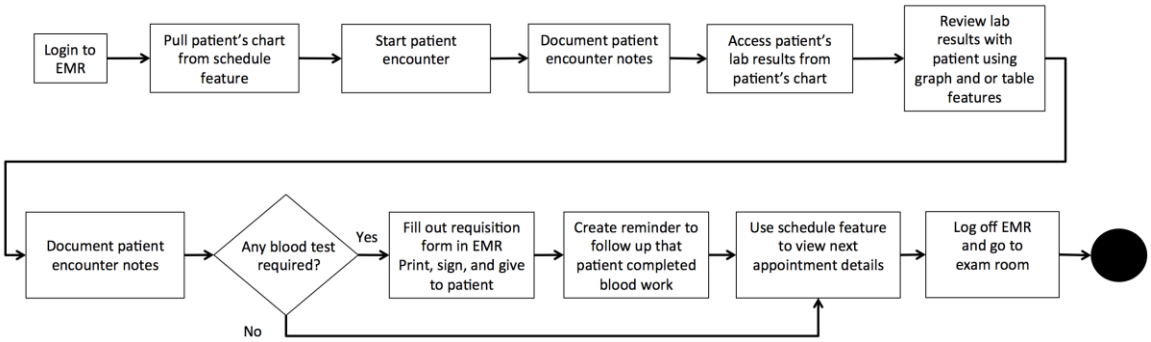

Figure 6. 7 Future-state process of laboratory results management during patient's visit.

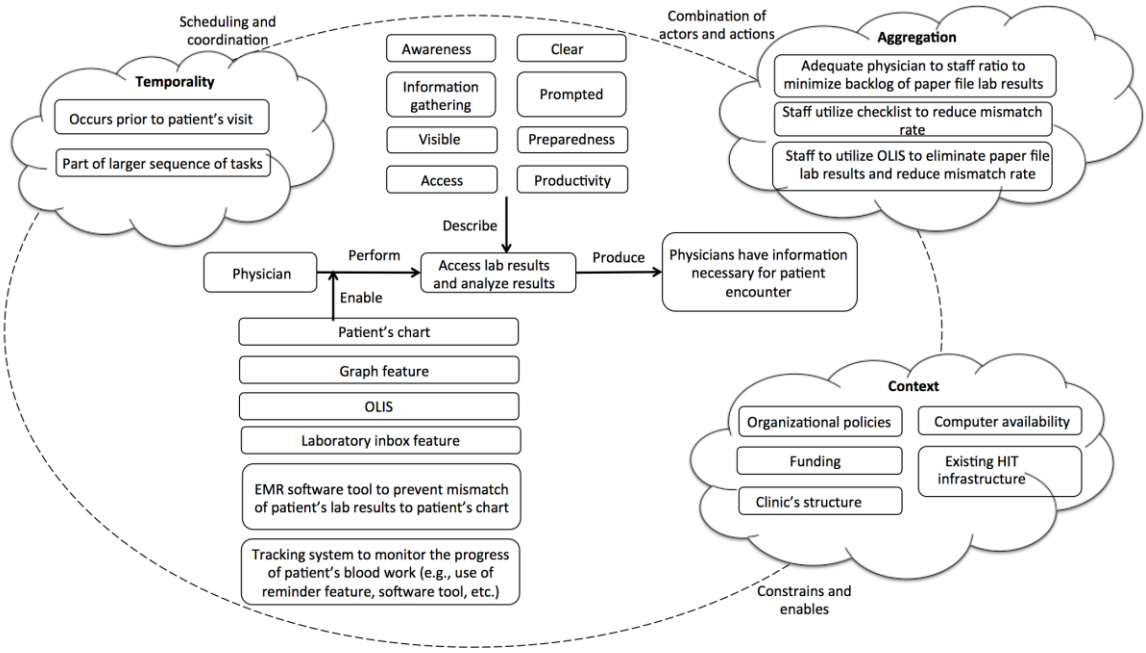

Figure 6. 8 Laboratory results management workflow elements prior to patient's visit.

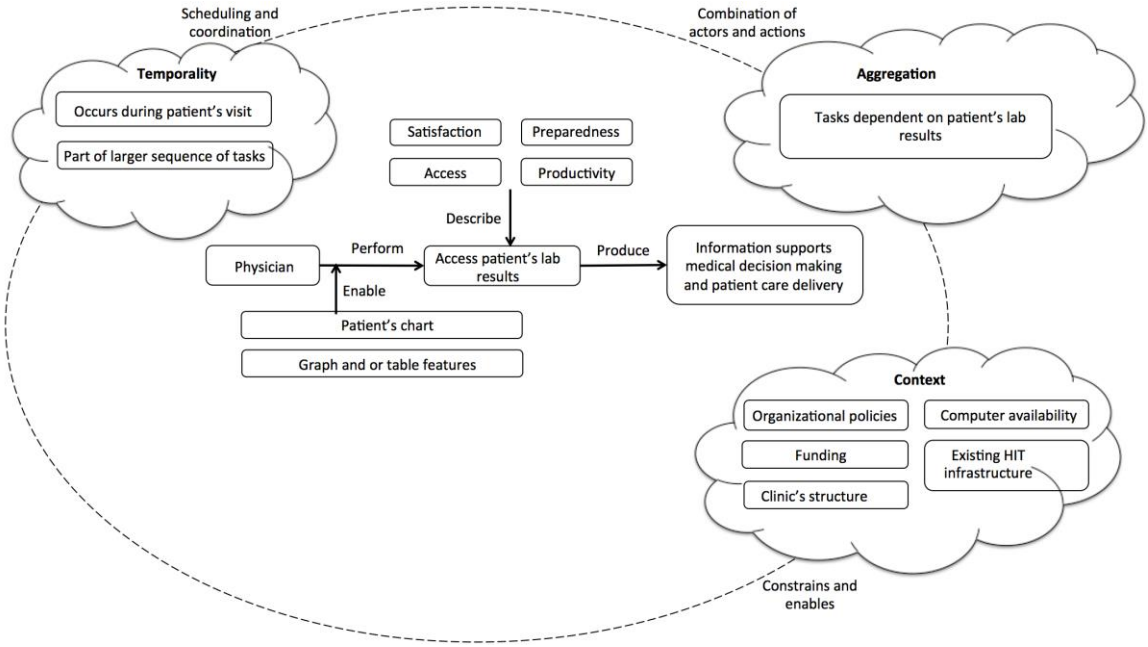

Figure 6. 9 Laboratory results management workflow elements during patient's visit.

6.4 Discussion

6.4.1 Principal Results

This study recommends six future-state improvements to streamline laboratory results management by primary care physicians:

1) The physician analyzes results prior to patient encounters. This ensures physicians will be more prepared for the patient's visit by having the information they need, and provides them the opportunity to get additional information, which will inform the patient encounter. It could also

reduce potential delays during the patient's visit, allowing the physician to be more productive. This recommendation can be achieved through the publication of this study, which creates awareness about the benefits of reviewing and analyzing laboratory results prior to the patient encounter.

2) Laboratory results be available on the patient's chart prior to the patient's appointment, and a time interval be set for when results would be available on the patient's chart. This recommendation also reduces patient encounter time. As well, having an effective tracking system to monitor the progress of patients' blood work facilitates access to results, which in turn allows appropriate follow-up on test results, fostering the patient's safety if the results are critical.

3) Provide on-going training on EMR software updates and other laboratory repositories such as OLIS. With such support, physicians and support staff will be better informed regarding available sources and be able to make use of advanced features. Furthermore, maintaining an adequate physician-to-staff ratio can also enable timely access to results.

4) Reduce the mismatch rate of laboratory results to a patient's chart. Granted that mismatching results rarely happens, reducing its occurrence will lessen the need for physicians' time to verify that results are matched to the appropriate patient's chart, which in turn reduces patient encounter time. In addition, inaccurate data sharing and inapt consultation with the patient will be prevented, thus not compromising patient safety. Furthermore, it forestalls patients' lack of

confidence as they are less likely to be exposed to a mismatch. In lean management, preventing errors or highlighting errors so they are not passed down to the next operation is a foundational quality improvement tool known as poka-yoke, a Japanese term that means mistake proofing [47]. Thus, as suggested in the future-state recommendations, using a checklist (paper or electronic) or a software tool at the source can help prevent human error while matching scanned files to a patient's chart.

5) Maintaining adequate physician-to-staff ratio to minimize backlog. This would allow laboratory results to be available during patient encounters and reduce the possibility of delaying patient visits and unnecessary follow-up appointments. As well, the timely availability of laboratory results frees physicians to work on other tasks. One study found that many major hospitals in Ontario are not designed to electronically send lab results to EMRs. Instead, results are usually faxed, resulting in delays caused by time spent matching the fax to the patient record [12]. Thus, by using OLIS, the need to scan paper files and attach results to a patient's chart can be eliminated.

6) Having a tracking mechanism for patient's laboratory results in the EMR software. This adds value to the physician's laboratory results management workflow by having an effective test result management system, thus enabling physicians to communicate test results to patients in a timely fashion, respond to test results and take clinically appropriate action in a timely fashion, ensure that test results are not lost or missed, and most importantly, promote patient safety. The

Ontario Medical Association, responsible for the political, clinical, and economic interests of physicians in the province of Ontario, has recognized the need to improve the co-ordination of care between physicians and patients [50]. In May 2018, a draft policy was created that proposed physicians meet certain requirements in order to enhance continuity of care. One of the proposed requirements was for physicians to have a robust test management system that would track test results for high-risk patients and verify whether or not the patient had taken the test and that the result had been sent to the physician [51, 52]. Thus, having a standard tracking mechanism as recommended in this study would facilitate this requirement proposed for physicians in Ontario.

6.4.2 Strengths and Limitations

A main strength of our study is the use of direct observation, which provided a rich description of workflow, particularly since it is typically difficult for an expert to describe their workflow, as many activities of the process are subconscious [26]. Direct observation provided invaluable data on workflows that would not have been explored through other techniques such as interviews or surveys. In addition, any discrepancies that arose during observations were clarified with participants after the observation. Moreover, process maps were validated with participants, which adds to the validity of the study [38]. Thus, using triangulation methods, such as member checking, to validate results and using multiple sources to collect data strengthened the quality of the study's findings [28]. Another strength is the rich descriptions of data

collection, analysis and results provided in the study, which can provide readers with insight about how to apply the findings to their context [28].

Our work has some limitations. First, in creating the process maps, we assumed that when a physician reviews the laboratory results it was a straightforward matter, which may oversimplify the process since primary care is a complex clinical environment. In addition, we were limited by the availability of the physicians, and as such, observations did not take place after clinical hours. Thus, any additional rich information that may have emerged after clinical hours was not captured in this study. Nonetheless, having a question period with the physicians after observations helped to address any gaps. Furthermore, the process maps only consider one actor, the primary care physician. Including other actors such as nurses, clerks, or clinical managers would provide another layer to the process map and expand on issues regarding access to laboratory results and backlogs.

Future research considerations include incorporating a subcomponent process map for a specific blood test (e.g., thyroid stimulating hormone), since our process maps only provided a high-level view of data results management.

6.5 Conclusions

The six improvement strategies recommended in this study could make three significant contributions: (1) give novel insight to assist in streamlining the workflow processes of primary care physicians who use EMRs for laboratory results management, (2) provide key decision-

makers (primary care professionals, EMR vendors, Ontario Medical Association) with vital information to make informed decisions about enhancing the optimal use of EMRs for laboratory results management and thus enrich primary care practices' business models, and (3) promote the quality of care for patients living with chronic diseases, which in turn, will help address the burden of chronic diseases.

Summary Points

What was already known:

- Electronic medical records and their features have been shown to facilitate chronic disease prevention and management.
- There is variation in the use of EMRs among primary care practices and as such, some primary care practices are not benefiting from EMRs as intended.
- Workflow analysis and lean methods are widely used in health care settings to analyze clinical workflow that involves health information systems and so improve processes.

What this study adds to our knowledge:

- Applying workflow analysis and lean methods streamlines the current-state process of laboratory test results management by primary care physicians using EMRs.
- Presently, when laboratory results are not available in a patient's chart (due to backlog, etc.), physicians must access the laboratory results on their own from among four different sources (OLIS, laboratory inbox, paper file, reaching out to support staff).

However, in the future state, laboratory results will be accessed by support staff and made available to physicians in a patient's chart prior to a patient's visit. *This would eliminate the time and additional steps taken by physicians to search for results.*

- Analysis of laboratory results was done during a patient's visit by the majority of physicians observed, whereas in the future, laboratory results will be analyzed prior to a patient's visit. *This would eliminate the time and additional steps taken by physicians to analyze laboratory results while they are with the patient.*
- During observations, we found that participants who analyzed results prior to a patient's visit practiced in a capitated payment model and participants who did not look at patient's laboratory results prior to the patient's visit practiced or had previously worked in a fee-for-service payment model. Regardless of the payment model, it is more advantageous for physicians in primary care practices to analyze results prior to a patient's appointment, thus reducing patient encounter time, being better prepared prior to patient encounters, and fostering patient safety.

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drafts of the manuscript. All authors read and approved the final manuscript. As well, we would like to acknowledge BP&M Consulting Inc. for its expertise in Lean management and support in the creation of the process maps.

Conflicts of Interest

None declared.

Abbreviations

EMR: Electronic Medical Record
OLIS: Ontario Lab Information System
FHO: Family Health Organization
FHT: Family Health Team

Appendix 1

Current-state process maps
[PDF File, 724 KB – Appendix 1.pdf]

Appendix 2

Future-state process maps
[PDF File, 863 KB – Appendix 2.pdf]

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Chapter Seven. Discussion

Chapter 7 provides a summary of the dissertation findings related to factors influencing the mature use of EMR features and recommendations that enhance PCPs' current-state processes of laboratory results management using EMRs. In this chapter, I also discuss the implications of the dissertation findings for stakeholders and address the dissertation's strengths and limitations. Finally, the chapter concludes with suggestions of future research opportunities.

7.1 Summary of Dissertation Findings

7.1.1 Systematic Review

In the systematic review, we identified 14 studies that focused on barriers and facilitating factors that influenced PCPs' mature use of EMR features that fell into one of the following five categories: technology, people, organization, resources, and policy (Chapter 4). Eligible studies reporting barriers to PCPs' mature use of EMRs identified the barriers as concerns about the EMR system's functionality, lack of physician awareness of EMR functionality, limited physician availability to learn more about EMRs, the habitual use of successfully completing clinical tasks using only basic EMR features, business oriented organizational objectives, lack of vendor training, limited resource availability, and lack of physician readiness. Eligible studies that reported on facilitating factors of PCPs' mature use of EMRs identified motivation of physicians, user satisfaction, coaching and peer mentoring, EMR experience, gender, physician

perception, transition planning for changes in roles and work processes, team-based care, adequate technical support and training, sharing resources, practices affiliated in an integrated delivery system, financial incentives, and policies to increase EMR use as having a favourable impact on PCPs' mature use of EMR features. Most of the studies were conducted in the US and Canada. One study was conducted in Israel and another was an international study conducted in 10 countries: Australia, Canada, France, Germany, Netherlands, New Zealand, Norway, Switzerland, UK, and US.

7.1.2 Qualitative Study

We also conducted a qualitative study, guided by the CAF, in which we used directed content analysis to explore the factors that influence PCPs' use of advanced EMR features to support CDPM (as identified by PCPs in Ontario) and to extend the CAF to include PCPs' perceptions of how their use of EMRs for performing clinical tasks has matured (see Chapter 5). A total of nine face-to-face interviews were conducted from January 2017 to July 2017. Dimensions of the CAF emerged from the data, and one new dimension was derived: PCPs' perception of their maturity of EMR use. PCPs identified the following key factors that impacted their use of advanced EMR features: performance of EMR features, information quality of EMR features, training and technical support, user satisfaction, provider's productivity, personal characteristics and roles, cost benefits of EMR features, EMR systems infrastructure, funding, and government leadership.

7.1.3 Process Mapping Study

We subsequently used an observational qualitative method to explore how EMRs and their features, specifically those designed for laboratory results management, are integrated into PCPs' workflows to facilitate CDPM (Chapter 6). Process mapping was used to develop and visualize the current state of PCPs' processes in order to identify waste conditions that disrupt the process flow and streamline current-state processes, which helped to recommend a future-state process. Six improvement strategies were recommended to enhance PCPs' current-state processes of laboratory results management using EMRs: (1) that physicians analyze patients' laboratory results prior to meeting them, (2) that laboratory results are available on the patient's chart prior to the patient's appointment, (3) that physicians and support staff receive on-going training so that they are aware of the interfaces of new laboratory repositories, (4) that a checklist or a software tool be used to reduce the mismatch rate of laboratory results to a patient's chart, (5) that an adequate physician-to-staff ratio be maintained to minimize backlog, and (6) that a mechanism (e.g., use of EMR reminder feature or a software tool) be used to track patients' laboratory results in their EMR.

7.2 Implications for Stakeholders

7.2.1 Implications for Organizations responsible to drive EMR maturity and Medical Education Associations

Organizations responsible to drive EMR maturity such as OntarioMD and Canada Health Infoway can make use of the key factors found in this dissertation to determine strategies to increase the mature use of EMR features by PCPs in Ontario and beyond. Our systematic review found that the key factors "team-based care" and "practices affiliated in an integrated delivery system" facilitated the mature use of EMR features by PCPs. Initiatives such as Ontario's funding of FHTs (a team-based model) (Rosser, Colwill, Kasperski & Wilson, 2011) and Ontario certified EMRs, are recommend to encourage PCPs to join an integrated delivery system practice. As well, in the process mapping study variations on the practice patterns workflows were found. For instance, participants that worked or previously worked in a fee-for-service funding model analyzed results during the patient's encounter. Whereas participants that analyzed results prior to the patient's encounter were from a FHT practice model. Thus, this finding further supports the need to develop policies that encourage primary care physicians to join an integrated delivery practice model such as FHTs.

The systematic review also found that financial incentives and policies that increase EMR use had a favorable impact on PCPs' use of advanced EMR features. Similarly, the qualitative study found that PCPs believe that funding and government leadership play a key role in

facilitating their use of advanced EMR features. Thus, polices that provide technical and financial incentives (e.g., grants or reimbursements) may influence primary care practices to orient their organizational objectives towards maturing physicians' EMR use rather than being business-oriented (e.g., focused on operational efficiency), a barrier found in the systematic review study. As well, sufficient funding may ensure that practices have an adequate physician-to-staff ratio to avoid the backlog of unscanned paper-based patients' test results or reports, a barrier identified in the process mapping study.

In addition, policies that provide sufficient technical and financial incentives to support the sharing of resources and that facilitate adequate technical support and training can promote PCPs' perceptions regarding the cost benefits of EMR features, while ensuring sufficient vendor training and resource availability. These are key factors identified in the systematic review and qualitative study that facilitate the mature use of EMRs by PCPs. OntarioMD provides primary care practices that are affiliated with an OntarioMD-certified EMR with access to Hospital Report Manager and OLIS (OntarioMD, 2020). This strategy is advantageous in maturing EMR use since these advanced features facilitate resource sharing by allowing practices to receive patients' laboratory results and diagnostic imaging reports from other health care facilities (e.g., hospitals). In addition, the advanced feature OLIS can address the barrier of poor EMR infrastructure, that is, the lack of direct links with hospitals and other health care facilities, which were cited in the qualitative study. Moreover, education and training of all clinicians and not

only primary care physicians plays an important role to the support of mature use of EMRs, which was a key recommendation from the process mapping study. By providing on-going training on EMR software updates and other advanced EMR features, clinicians will be better informed regarding available sources and make better use of advanced EMR features. As well, invest in training clinicians on not only advanced EMR features but on technical skill sets (e.g., information management skills, such as data entry and retrieval) that are necessary for effective interaction with the EMR (Kuziemsky, 2015).

Furthermore, policies that require vendors to incorporate PCPs when implementing advanced EMR features from the on-set would ensure that the EMR feature "fits" the main medical tasks of PCPs. The lack of fit between EMR features and PCPs' values, priorities, and work practices was highlighted in other studies (Cifuentes, Davis, Fernald, Gunn, Dickinson, & Cohen, 2015; Makam et al., 2014; Walter & Lopez, 2008). Thus, OntarioMD may wish to add this as a requirement for vendors when certifying EMRs. Doing so may facilitate PCP user satisfaction with advanced EMR features and PCP perception that the EMR feature is productive, which are key findings from the systematic review and the qualitative study. Moreover, OntarioMD should require certified EMR vendors to have EMR features that reduce the mismatch rate of laboratory results to a patient's chart and that tracks patients' laboratory results in their EMRs. These are two recommendations from the processing mapping study that would help optimize the laboratory results management workflow of Ontario PCPs. As well, the

Ontario Medical Association (2019), which is responsible for the political, clinical, and economic interests of physicians in the province of Ontario, proposed that having a robust test management system that would track test results for high-risk patients be mandatory for physicians (College of Physicians and Surgeons of Ontario, 2018; Ontario Medical Association, 2018). Having the tracking mechanism already implemented in the EMR system by vendors would facilitate this requirement proposed for physicians in Ontario.

Medical education associations such as the Association of Faculties of Medicine of Canada (AFMC; 2020), may wish to consider implementing strategies to introduce the use of EMR systems and their advanced features to medical students. This way physicians will be introduced to the technology from the on-set, providing early EMR experience to future practicing physicians. This may also address the barrier of personal characteristics (e.g., less EMR experience) and roles (e.g., laggards), which were key factors found in the systematic review and qualitative study.

7.2.2 Implications for PCPs and Practice Managers

The process mapping study demonstrated the importance of PCPs analyzing patients' laboratory results prior to the patient's appointment. By doing so, PCPs will be more prepared for the patient's visit because they have the information they need at hand. It could also reduce potential delays during the patient's visit, allowing the physician to be more productive.

Furthermore, primary care tasks may not all transition equally to virtual care. A major challenge is that many of the healthcare process we are trying to automate lack maturity, lack a standardized process and the process is still evolving. Thus, making it challenging to develop health information technology to support healthcare processes. To address this challenge, rules of engagement for tasks need to be defined prior to automating tasks (Kuziemsky, 2015). Moreover, trade offs or losses to primary care physicians' workflow needs to be discussed and if possible negotiated with providers (Kuziemsky, 2015).

Practice managers may consider transition planning for changes in roles and work processes when introducing advanced EMR features. As well as encourage coaching and peer mentoring within the practice, which are key factors found in all three studies, the systematic review, qualitative study, and process mapping study, that promote the mature use of EMRs by PCPs. OntarioMD's Peer Leader Program is one strategy that can facilitate these factors (OntarioMD, 2019). The program is a network of over 60 Ontario health care professionals who are expert users of OntarioMD certified EMRs. These experts provide mentoring and consulting services to primary care practices by demonstrating how to use their EMR systems and its features more efficiently and how to access additional features to optimize workflow and improve clinical decision making (OntarioMD, 2019). Such a program may also address the lack of physician awareness of EMR functionality and limited physician availability to learn more about EMRs, which were barriers found in the systematic review, in addition to motivating

physicians, a facilitator identified in the systematic review. Practice managers may wish to consider the QIDS program as it may address the lack of on-site technical support from the vendor, which created additional costs to practices such as hiring staff to address technical issues, reported in the qualitative study. Moreover, practice managers should assign staff members to ensure that laboratory results are available on the patient's chart prior to the patient's appointment. This was one of the key recommendations from the process mapping study. Doing so can reduce PCP–patient encounter time.

7.2.3 Implications for Vendors

Vendors should implement advanced EMR features with PCPs from the on-set. This would alleviate concerns about the EMR system's functionality, the lack of physician readiness to learn advanced EMR features, and the habitual use of successfully completing tasks using only basic EMR features. In addition, this recommendation would foster physician's positive perceptions of advanced EMR features, and promote user satisfaction of advanced EMR features, which were key factors found in the systematic review and qualitative study that facilitate the mature use of EMRs by PCPs.

A study that compared the automation of information technology in primary care physician offices in Denmark and New Zealand found that primary health care organizations worked closely with EMR vendors to develop EMR functionality (Protti, Bowden, & Johansen, 2008). As well, to address barriers found in the systematic review and qualitative study, vendors

should consider developing training material together with PCPs to ensure that the material is sufficient and meets the needs of PCPs, in addition to being based on clinical practice rather than theory. Other studies on the adoption of EMRs have also pointed out that adequate education and training is essential to support the uptake of EMRs (Adaji, Schattner, & Jones, 2008; Samoutis, Soteriades, Kounalakis, Zachariadou, Philalithis, & Lionis, 2007). Thus, targeted interventions as discussed above are an asset to overcome the barriers identified in this dissertation and facilitate the mature use of EMRs by PCPs.

7.2.4 Implications for Patients and Population Health

The goal of this dissertation is to contribute to the field of population health to promote the delivery of care for patients with chronic diseases living in Ontario. The hoped-for outcome of this dissertation is to establish evidence-based recommendations that will assist key decision-makers (e.g., managers of primary care practices, PCPs, EMR vendors, and organizations responsible to drive EMR maturity) to identify the barriers to and facilitating factors of mature use of EMR features that supports CDPM, and to make decisions about strategies to improve the use of EMR features that support CDPM workflow processes.

The mature use of EMRs by PCPs has the potential to provide a more effective delivery of CDPM, which in turn advances public health. Population health interventions focus on the interrelated factors that influence the health of populations over the life course and are designed

to improve the health and well-being of those populations (PHAC, 2004). This study has contributed to the science of population health by:

1) Identifying interrelated factors that influence PCPs' mature use of EMRs;
2) Introducing strategies to improve PCPs' work processes in laboratory results management while using EMRs, which will result in safer and more effective delivery of CDPM;
3) Creating the knowledge needed to improve the mature use of EMRs by PCPs.

In Ontario, the Primary Care Performance Measurement Framework (Health Quality Ontario, 2014) identifies cancer screening, CDPM, and management of risk factors (e.g., smoking) as both system- and practice-level priorities for population health. Thus, the findings from this dissertation can help build a richer picture of the benefits incurred by clinicians (practice-level) and the health system (system-level).

7.3 Study Strengths and Limitations

The findings of this multi-method dissertation provides a unique perspective on the factors that influence PCPs' mature use of EMRs. A key strength of the qualitative study is that physicians were interviewed in person, which provided a deeper understanding of their responses and allowed them to demonstrate certain EMR features. This, in turn, allowed us to observe the barriers and facilitating factors experienced by participants. In addition, the coauthors audited the results and two team members independently analyzed transcripts, which adds credibility to the

study. However, a limitation of the systematic review is using purposeful sampling, which may bias results by creating a homogeneous sample mix and as a result may reach data saturation faster with a smaller sample size. Furthermore, another limitation is that the great majority of studies are from Canada and the United States of America. One of the challenges in the health informatics literature is a common terminology. The term "mature EMR use" varied among studies and previous studies have highlighted that the literature in this field may be poorly referenced within bibliographic databases because terminology is not standardized, and there is no taxonomical consensus related to health information technologies. Moreover, in the data search strategy I used terms that reflected maturity and also used key words and Medical Subject Headings terms from studies that met eligibility. Terms such as meaningful use and mature EMR originated from the United States of America and Canada from studies that met eligibility. Thus, explaining why the great majority of studies are from North America. Furthermore, during full-text screening of studies, papers not written in English were excluded due to limited resources to translate the study into English.

For the process mapping study, a main strength is the use of direct observations, which provided a rich description of workflow that could not have been explored through other techniques such as interviews or surveys. In addition, triangulation, which entailed member checking to validate results and using multiple sources to collect data, was used to strengthen the quality of the study's findings (Unertl, Novak, Johnson, & Lorenzi, 2010). As for the systematic

review study, a key strength was using the AMSTAR instrument to appraise our study; the study was rated as meeting 14 out of 16 criteria (two was not applicable because we did not conduct a meta-analysis and we did not assess for publication bias) (Sharif, Janjua-Sharif, Ali, & Ahmed, 2013; Shea et al., 2017). In addition, although Lean methods does not have a theoretical basis, this study used empirical methods such as interviews and observations, which has been found in other studies that ethnographic methods can be useful in explaining non-use of information technology (Cresswell, Worth, & Sheikh, 2010; Greenhalgh & Russell, 2010), and are increasingly recognized as a valuable approach to evaluating and implementing health information technologies (Forsythe, 1992; Greenhalgh & Swinglehurst, 2011). Moreover, Lean methods uses an iterative approach that engages users, which has been highlighted in a previous study (Kuziemsky, 2015) that health information technology users need to be involved as much as possible to enable them to understand the nature of health information technology induced changes and how it will impact their workflow. Thus, by engaging users in the understanding of problems can increase the chance of successful health information technology design and implementation (Kuziemsky, 2015).

However, a limitation of this dissertation is that it relies heavily on human observation and interviews and thus is vulnerable to subjectivity bias. But that limitation may be the price of applying the expert interpretation of PCPs to factors that influence their mature use of EMRs.

Several other limitations that could affect the reproducibility of results in applying an intervention of this nature in other settings can also be identified. These include variability of utilizing the findings across clinics in Canadian provinces other than Ontario, the variability of applying the recommended strategies to the mature use of EMRs to health care professionals other than PCPs, and the variability in available functionality and supports across EMR products.

Furthermore, patient health outcomes were not examined in the study, which is recommended (Renders et al., 2001). Other possible sources of bias include "researcher affect" (Jackson & Verberg, 2007, p. 283), based on the researcher's relationship with the program being evaluated. This was mitigated by including three academic advisors who provided feedback on the interpretation of results.

7.4 Future Research

This research contributes to the literature by offering an in-depth look at the factors influencing PCPs' mature use of EMRs. It also provides a glimpse into the opportunities in several areas requiring further research. Conducting further qualitative and quantitative studies would help determine valid and reliable tools to measure the mature use of EMRs by PCPs. Furthermore, future work to validate the extended CAF would be of interest, which can be done by conducting a longitudinal analysis either qualitatively with interviews or quantitatively with surveys, to evaluate the effects of the postadoption factors over time to reflect the different maturity stages of the user.

Moreover, future work that assesses the feasibility of the recommendation would be of great benefit. This can be done by using a combination of qualitative and quantitative methods by sending out a survey and conducting interview with physicians, practice managers, other staff memebers since the recommendations will have an impact on other members as well in the practice and with vendors and ask questions such as whether the recommendations are financially possible? Will it be accepted by other members in the practice? Are the technical capabilities available in the practice to support the recommendation? Are there any legal or regulatory conditions that can be an obstacle?

Other studies have recommended that research should take into account the effect on patient outcomes and focus on population management improvement when studying the meaningful use of EMR (Crosson, Ohman-Strickland, Cohen, Clark, & Crabtree, 2012; Grevier et al., 2012). Thus, tools required to measure the impact of the mature use of EMRs by PCPs on the delivery of CDPM and the effect on patient outcomes would be of great benefit.

Evaluating the effectiveness of interventions is another important element of population health (Health Canada, 2001). Another future research area would be to evaluate the effectiveness of the strategies discussed in this dissertation that were recommended to increase the mature use of EMRs by PCPs. Furthermore, research on the role of EMR vendor support in improving EMR maturity would also be beneficial.

7.5 Conclusion

This dissertation's findings provides further layers to our understanding of mature EMR use and highlights areas where improvements to the mature use of EMRs by Ontario PCPs can be made. Thus, the publication of these results is both important and necessary for knowledge transfer. The findings from this dissertation provide further steps to improve EMR maturity, which has been shown to lead to improvements in care (Jones, Koziel, Larsen, Berry, & Kubatka-Willms, 2017). EMR use is a continuing journey of learning and improvement. EMRs can improve population health management, enable public health interventions, and support evidence-based policy. With the appropriate help to improve EMR maturity, practices can achieve their population health goals to the benefit of their patients.

Chapter Eight. Contribution of Collaborators

The chapter introduces and identifies the contributions of the collaborators; it was written in accordance with the guidelines of the Faculty of Graduate and Postdoctoral Studies at the University of Ottawa (2012). Contributions are discussed as they relate to individuals on the research team and other collaborators on the manuscripts. Chapter 8 concludes by acknowledging the stakeholders and research assistants who supported some aspects of the manuscripts and/or dissertation.

The Faculty of Graduate and Postdoctoral Studies at the University of Ottawa (2012) guidelines require that students writing manuscript-based dissertations describe their contribution to any of the manuscripts in depth and differentiate between their contributions and various coauthor contributions.

8.1 Research Team Collaborators

The primary researcher, RR, conceived of, participated in, and led all aspects of the research study as part of the fulfillment of the requirements of the degree of Doctorate of

Population Health (PhD) at the University of Ottawa. The collaborators were RR's dissertation supervisor, Dr. Sanni Yaya MSc, PhD (SY), and two committee members, Dr. Craig Kuziemsky, BSc, Bcom, PhD (CK) and Dr. Jay Mercer MD, CCFP, FCFP (JM).

All committee members participated in different phases of the dissertation project. They provided content expertise and approved the research proposal. For the manuscripts, they provided consultation and feedback, participated in the validation of data, contributed intellectual content to the manuscripts, and approved the final versions.

RR has bachelor's and master's degrees of applied science in electrical engineering from the University of Ottawa. RR's master's degree project was focused in biomedical engineering, for which she designed and developed an automatic volume setting feature for Siemens's environmentally sensitive hearing aids. RR worked as an electrical engineer in Ottawa, Canada, for the company Global Spatial Technology Solutions Inc., and in Toronto, Canada, for the company Bombardier Inc., where she was involved in risk management, project management, and quality assurance. RR then worked for the Public Health Agency of Canada in Ottawa as an analyst, where she led and managed working groups and provided scientific support to develop evidence-based clinical practice guidelines; she successfully published one of the guidelines (cognitive impairment) with the Canadian Medical Association Journal. She also worked for the Marketed Pharmaceuticals and Medical Device Bureau at Health Canada in Ottawa, where she conducted research related to adverse events from medical devices that were available on the

market. RR also received a four-year admission scholarship for doctoral studies from the University of Ottawa.

SY is a Full Professor of Economics and Global Health and the Director and Associate Dean of the School of International Development and Global Studies. He is Editor of Health and Society at the University of Ottawa Press and was Editor of the Innovation Journal. He also serves as Associate Editor for Biomed Central Public Health.

Professor Yaya was previously a Postdoctoral Research Fellow at Yale University and a Senior Visiting Scholar at New York University (NYU). Currently, he is a visiting professor at Oxford (UK) and a visiting professor at several universities, including Harvard University (Chan School of Public Health) and Johns Hopkins (Bloomberg School of Public Health).

Professor Yaya has experience in the design and implementation of randomized controlled trials and observational epidemiologic studies of maternal and child health, infectious diseases and chronic diseases. Yaya has published numerous books, book chapters and technical reports. His research articles have appeared in leading peer-reviewed journals, including The Lancet, Health Policy and The International Journal of Medicine (Oxford University Press). Additionally, Professor Yaya has been a senior advisor for several health intervention programs and international development projects funded by the World Health Organization, United Nations International Children's Emergency Fund, United Nation Development Program, The World Bank, private foundations, and many governments.

Kuziemsky is the Associate Vice-President of Research at MacEwan University, Edmonton, AB, Canada. He was a full professor and University Research Chair in Healthcare Innovation in the Telfer School of Management at the University of Ottawa. He was awarded the University of Ottawa 2013 Young Researcher of the Year Award in the Social Sciences and Humanities. In his research, CK has developed innovative approaches for modelling collaborative health care delivery to support the design of information and communication technology to support different collaborative contexts. His studies of collaboration have used approaches such as complexity theory to understand the nature of collaborative interactions in different healthcare settings such as clinical health care and public health for disaster management. CK has published numerous books, book chapters and peer-reviewed journals. His research articles have appeared in leading peer-reviewed journals, including the Journal of Medical Internet Research, Journal of Health Organization and Management, Journal of Innovation in Health Informatics, and International Journal of Medical Informatics.

Dr. Mercer is a family physician and medical director at Ottawa's Bruyère Family Medicine Centre. He is also the co-director at the University of Ottawa's uOttawa-Guyana Family Medicine Residency Training Program. Dr. Mercer's research focuses on primary care and electronic health (e-health). He has been involved in many e-health initiatives in Ontario, including those related to EMRs. JM has published numerous leading peer-review journals,

including the Journal of Medical Internet Research, Journal of Evaluation in Clinical Practice, BMC Public Health, Annals of Family Medicine, and Telemedicine and e-Health.

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Appendices

Appendix A: Definition of factors from Clinical Adoption Framework

(Lau et al., 2007, 2011)

Micro-Level		
Dimension	Category	Definitions of Suggested Measures
System	Functionality	Type of features and level of decision support (i.e., report or view, reference, reminder, alert, assist and guide)
	Performance	Accessibility (distance and availability), reliability (up- and downtime) and system response time
	Security	Type of features
Information	Content	Completeness, accuracy, relevance and comprehension
	Availability	Timeliness, reliability and consistency of information when and where needed
Service	Responsiveness	User training, ongoing technical support and availability of support
Use	Use behaviour and pattern	Frequency, duration, location, type or nature and flexibility of perceived usage
	Self-reported use	Frequency, duration, location, type or nature and flexibility of perceived usage
	Intention to use	Proportion of and factors for current non-users to become users

Satisfaction	Competency	Knowledge, skills and experience
	User satisfaction	Perceived expectations, value, information/system/service quality and use of the system (including provider-patient interaction, preference, comfort and experience)
	Ease of use	User-friendliness and learnability
Net benefits	Quality	Patient safety: • Preventable adverse events – near misses and near errors • Surveillance – post marketing and public health (communicable disease surveillance) • Reduction in patient risks and safety-related reportable drug and device events
		Appropriateness and effectiveness: • Adherence and compliance with benchmark, policy or practice standards and guidelines • Self-reported practice or practice captured in the system • Immunization and testing and other relevant rates • Continuity of care: (1) information, relational and management continuity (2) by individuals or multidisciplinary teams or geographically dispersed teams and (3) access to information and effectiveness of general practitioner and specialist referral
		Health outcomes: • Clinical outcomes • Change in health status attributable to the eHealth intervention
	Access	Ability of patients and providers to access services (e.g., Telehomecare): • Availability, diversity and consolidation of service

		• Timeliness, geographic, financial and cultural or linguistic – removal of inequitable barriers (including affordability, acceptability and accommodation)
		Patient and caregiver participation: patient self-management and access to his or her information
	Productivity	Efficiency: • Provider resource use • Improvement short term in outputs versus inputs and longer term in care continuity • Improved health system management capability • Improved patient efficiency (e.g., more efficient scheduling of preoperative testing) • Non-monetary effects
		Care coordination: • Care provision by team • Continuity of care across continuum
		Net cost: • Monetary avoidance • Monetary reductions, savings
Meso-Level		
Dimension	Category	Definitions of Suggested Measures
People	Individuals and groups	Types of individuals/groups that can affect the adoption of an HIS, including patients/clients and families, healthcare providers and managers, policy planners and stakeholder groups
	Personal characteristics	Degree to which an individual's age, gender, education, experience and expertise can affect the adoption of an HIS
	Personal expectations	Degree to which an individual believes HISs are important, can improve job performance and that infrastructures exist to support its adoption

	Roles and responsibilities	Position, function and obligation of an individual/group in relation to HIS adoption, e.g., being a stakeholder, leader, champion and project sponsor
Organization	Strategy	Set of coordinated activities designed to achieve the overall mandate and objectives of the organization, including HIS adoption
	Culture	Ingrained set of shared values, beliefs and assumptions acquired by members of an organization over time, including their views toward HISs
	Structure and processes	Organizational functioning, including governance, configuration, reporting relationships and communication, as well as business and patient care processes such as continuity of care
	Info- and infrastructure	HIS governance/management, technical architectures, information assets, level of integration and privacy/security in place or planned
	Return on value	Economic return on HIS investment in terms of cost benefit, effectiveness, utility and avoidance, business case, return on investment, value propositions and benefits realization
Implementation	Stage	Economic return on HIS investment in terms of cost benefit, effectiveness, utility and avoidance, business case, return on investment, value propositions and benefits realization
	Project	Planning, activities and resources for HIS adoption, including scope, objectives, constraints, targets, governance, methodology, commitment, communication, training, risks, monitoring, reporting and expectations
	HIS-practice fit	Degree of fit between the HIS and organizational work practices, and the extent of change from HIS adoption

Macro-Level		
Dimension	Category	Definitions of Suggested Measures
Healthcare standards	HIS standards	Types of data, messaging, terminology and technology standards that influence the healthcare industry as a whole with respect to HIS adoption
	Performance standards	Types of organizational performance standards in place, such as those for accreditation of healthcare facilities and performance targets
	Practice standards	Desired level of professional competency, knowledge, skills and performance in the workplace, including HIS adoption
Funding and incentives	Remunerations	Types of compensation available, such as alternative payment schemes to entice change at the individual, practice and organizational levels
	Added values	General expectations on the return on value from the adoption of an HIS, such as improved patient safety and access to care
	Incentive programs	Types of reward programs available that entice change at the individual, practice and organizational levels
Legislation, policy and governance	Legislative acts	Types of HIS-related legislative acts, such as health information and privacy laws that govern the adoption of HISs
	Regulations and policies	Types of HIS-related regulations/policies, such as data access and security/privacy guidelines
	Societal trends	General expectations of the public toward healthcare and HISs
	Political trends	General political climates toward healthcare and HISs

Societal, political and economic trends	Economic trends	General economic investment climates toward healthcare and HISs

HIS=health information system

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Appendix B. Ovid MEDLINE database

<1946 - June 2019> Search Strategy Keywords

1. Electronic Health Records/
2. ((electronic or computerized) adj2 (health or medical*) adj2 record*).ti,ab,kw.
3. electronic medical record/ or electronic medical record system/
4. medical informatics/ or medical information system/
5. medical information system*.ti,ab,kw.
6. e-health.ti,ab,kw.
7. ehealth.ti,ab,kw.
8. 1 or 2 or 3 or 4 or 5 or 6 or 7
9. physicians, family/ or physicians, primary care/
10. general practitioner/
11. ((primary or family or general) adj2 (physician* or doctor* or practitioner*)).ti,ab,kw.
12. (primary adj2 care).ti,ab,kw.
13. family practice*.ti,ab,kw.
14. general practice/ or family practice/
15. Primary Health Care/
16. general practice*.ti,ab,kw.
17. 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16
18. (maturity* or maturing).ti,ab,kw.
19. "Diffusion of Innovation"/
20. Diffusion of Innovation*.ti,ab,kw.
21. scalability*.ti,ab,kw.
22. scale up.ti,ab,kw.
23. sustain*.ti,ab,kw.
24. ((matur* or meaningful or optimal* or effective* or advanc* or enhanc* or proficient*) adj3 use*).ti,ab,kw.
25. assimilat*.ti,ab,kw.
26. Attitude to Computers/
27. 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26
28. 8 and 17 and 27

Appendix C. Consent forms

Physician Consent Form Semi-structured Interviews

Purpose of the Study: The purpose of the study is to obtain perspectives about how primary health care (PHC) professionals in Ontario use electronic medical records (EMR) features to support chronic disease and prevention management (CDPM). The objective of the study is to identify factors that primary health care professionals experience when using EMR features to ensure proper use of the EMR in order to support CDPM. Process maps will be developed to provide a visual representation of how EMRs and their features are used to support CDPM.

Participation: My participation will consist of being interviewed and asked a set of questions (60 to 90 minutes in length). Interviews will be audio-recorded. The interview session will be scheduled right after the observation period during my break or after my working hours (date and time TBD). The number of interview sessions that will be done depends on data saturation that will be determined by the Principal Investigator.

Risks: My participation in this study will entail that I volunteer business information that may cause me to feel uncomfortable. I have received assurance from the researcher that every effort will be made to minimize this risk by ensuring that my name and career title remains anonymous.

As well, I will have the opportunity to review transcripts and process maps via email using password protection of documents as a security measure.

Benefits: There are no direct benefits to participants. However, my participation in this study may improve the effectiveness of physicians' using EMRs within their clinical practice, improve the delivery of CDPM, and achieve successful adoption of EMRs at PHC practices. This study will contribute to the advancement of knowledge by developing a rich and useful set of recommendations to enhance how PHC professionals use EMR features to support CDPM and to ensure that EMRs are successfully adopted and sustained within their environment.

Confidentiality and anonymity: I have received assurance from the researcher that the information I will share will remain strictly confidential. I understand that the contents will be used only for publications and that my confidentiality will be protected. **Anonymity** will be protected in the following manner by removing my name and career title from the data collection and that my identity will not be revealed in publications.

Conservation of data: The data collected from hard copy of interviews (i.e. notes) and electronic data from tape recordings of interviews and transcripts will be kept in a secure manner locked in a cabinet at the workstation of the principal investigator located at the University of Ottawa. Only the principal investigator can access the cabinet. The data will be stored for a period of 5 years at which time they will be destroyed.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed.

Acceptance: I, *(Name of participant),* agree to participate in the above research study conducted by Rana Melissa Rahal of the Population Health Institute which the research is under the supervision of Dr. Sanni Yaya.

If I have any questions about the study, I may contact the researcher or her supervisor.

There are two copies of the consent form, one of which is mine to keep.

Participant's signature: *(Signature)* Date: *(Date)*

Researcher's signature: *(Signature)* Date: *(Date)*

Physician Consent Form Observations

Purpose of the Study: The purpose of the study is to observe how primary health care (PHC) professionals in Ontario use electronic medical records (EMR) features to support chronic disease and prevention management (CDPM). The objective of the study is to identify factors that primary health care professionals experience when using EMR features to ensure proper use of the EMR in order to support CDPM. Process maps will be developed to provide a visual representation of how EMRs and their features are used to support CDPM.

Participation: My participation will consist essentially of being observed by the principal investigator for approximately 2 to 3 hours in length. The observation will be during my working hours at the PHC practice where I work (date and time TBD). The number of observation sessions that will be done depends on data saturation that will be determined by the Principal Investigator.

Risks: My participation in this study will entail that I volunteer business information that may cause me to feel uncomfortable. I have received assurance from the researcher that every effort will be made to minimize this risk by ensuring that my name and career title remains anonymous. As well, I will have the opportunity to review transcripts and process maps via email using password protection of documents as a security measure.

Benefits: There are no direct benefits to participants. However, my participation in this study may improve the effectiveness of physicians' using EMRs within their clinical practice, improve the delivery of CDPM, and achieve successful adoption of EMRs at PHC practices. This study will contribute to the advancement of knowledge by developing a rich and useful set of recommendations to enhance how PHC professionals use EMR features to support CDPM and to ensure that EMRs are successfully adopted and sustained within their environment.

Confidentiality and anonymity: I have received assurance from the researcher that the information I will share will remain strictly confidential. I understand that the contents will be used only for publications and that my confidentiality will be protected. **Anonymity** will be protected in the following manner by removing my name and career title from the data collection and that my identity will not be revealed in publications.

Conservation of data: The data collected from hard copy of observations (i.e. notes) will be kept in a secure manner locked in a cabinet at the workstation of the principal investigator located at the University of Ottawa. Only the principal investigator can access the cabinet. The data will be stored for a period of 5 years at which time they will be destroyed.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering

any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed. In addition, patient participants will have the opportunity to decide whether or not they consent to the observation of their appointment.

Acceptance: I, *(Name of participant),* agree to participate in the above research study conducted by Rana Melissa Rahal of the Population Health Institute which the research is under the supervision of Dr. Sanni Yaya.

If I have any questions about the study, I may contact the researcher or her supervisor.

Participant's signature: *(Signature)* Date: *(Date)*

Researcher's signature: *(Signature)* Date: *(Date)*

Patient Adult Consent Form

Purpose of the Study: The purpose of the study is to observe how primary health care (PHC) professionals in Ontario use electronic medical records (EMR) features to support chronic disease and prevention management (CDPM). The objective of the study is to improve the quality of care for patients that have chronic diseases.

Participation: My participation will consist essentially of being observed by the principal investigator during my doctor's appointment. The principal investigator will not observe work processes that are not related to using EMRs (e.g., physical examinations) and the investigator will leave the doctor's room.

Risks: My participation in this study will entail that I will discuss with the doctor personal information that may cause me to feel uncomfortable because the researcher is in the same room observing the doctor. I have received assurance from the researcher that every effort will be made to minimize this risk by ensuring that my name is not recorded during the observations.

Benefits: There are no direct benefits to participants. However, my participation in this study may improve the delivery of patient care and specifically towards CDPM. This study will contribute to the advancement of knowledge by developing a rich and useful set of

recommendations to enhance how PHC professionals use EMR features to support CDPM and enhance the delivery of care for patients.

Confidentiality and anonymity: I have received assurance from the researcher that the information I will share will remain strictly confidential. I understand that the contents will be used only for publications and that my confidentiality will be protected. **Anonymity** will be protected in the following manner by removing my name from the data collection and that my identity will not be revealed in publications.

Conservation of data: The data collected from hard copy of observations (i.e. notes) will be kept in a secure manner locked in a cabinet at the workstation of the principal investigator located at the University of Ottawa. Only the principal investigator can access the cabinet. The data will be stored for a period of 5 years at which time they will be destroyed.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be destroyed. In addition, I will have the opportunity to decide whether or not I consent to the observation of my appointment. As well, the observation will not take place if I do not give consent.

Acceptance: I,_____*(Name of participant),* agree to participate in the above research study conducted by Rana Melissa Rahal of the Population Health Institute which the research is under the supervision of Dr. Sanni Yaya.

If I have any questions about the study, I may contact the researcher or her supervisor.

There are two copies of the consent form, one of which is mine to keep.

Participant's signature:_____*(Signature)* Date:

Researcher's signature:_____*(Signature)* Date:

Parental Consent Form Observations

Purpose of the Study: The purpose of the study is to observe how family doctors in Ontario use electronic medical records (EMR) and it's features to prevent and manage chronic diseases (for example, cancers and diabetes). The objective of the study is to improve the quality of care for patients that have chronic diseases.

Participation: My child's participation will consist essentially of being observed by the principal investigator during my child's doctor's appointment. The principal investigator will not observe work processes that are not related to using EMRs (e.g., physical examinations) and the investigator will leave the doctor's room.

Risks: My child's participation in this study will involve that my child will discuss with the doctor personal information that may cause him/her to feel uncomfortable because the researcher is in the same room observing the doctor. I have received assurance from the researcher that my child's name will not be recorded during the observations.

Benefits: There are no direct benefits to participants. However, my child's participation in this study can improve the quality of care for patients with chronic diseases. This study will

contribute to healthcare by developing recommendation for family doctors for the proper use of EMRs to improve the delivery of care for patients with chronic diseases.

Confidentiality and anonymity: The researcher told me that the information my child will share with the family doctor will remain strictly confidential. My child understand that the information the researcher will collect while observing the doctor work with their EMR will be used only for publications and that my child's confidentiality will be protected. **Anonymity** will be protected in the following manner by removing my child's name from the data collection and that my child's identity will not be revealed in publications.

Conservation of data: The data collected from hard copy of observations (i.e. notes) will be kept in a secure manner locked in a cabinet at the workstation of the principal investigator located at the University of Ottawa. Only the principal investigator can access the cabinet. The data will be stored for a period of 5 years at which time they will be destroyed.

Voluntary Participation: My child is under no obligation to participate and if he/she chooses to participate, he/she can withdraw (leave) from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If my child chooses to withdraw, all data gathered until the time of withdrawal will be destroyed. In addition, my child will have the opportunity to decide whether or not he/she consents to the observation of their appointment. As well, the observation will not take place if my child does not give consent.

Acceptance: I, *(Name of participant/parent/guardian),* agree to participate in the above research study conducted by Rana Melissa Rahal of the Population Health Institute which the research is under the supervision of Dr. Sanni Yaya.

If I have any questions about the study, I may contact the researcher or her supervisor.

There are two copies of the consent form, one of which is mine to keep.

Participant's signature: *(Signature)* Date: *(Date)*

Parent/guardian signature: *(Signature)* Date: *(Date)*

Researcher's signature: *(Signature)* Date: *(Date)*

Assent Form Observations

Investigators: Rana Melissa Rahal (PhD Student), Dr. Sanni Yaya (Thesis Supervisor)

Why you are here?

The family doctor wants to tell you about a study about children with chronic disease, such as cancers, diabetes or obesity. They want to see if you would like to be in this study. This form tells you about the study. If there is anything you do not understand, please ask your parent, your guardian or the study staff.

Why are they doing this study?

They want to see how the family doctor uses a computer called an Electronic medical record to help the delivery of care for children with chronic diseases.

What will happen to you?

If you want to be in the study these things will happen:

1. The study will last about the length of your visit with the doctor (approximately 15 minutes).
2. When you go to your doctor's office, the researcher will only be watching how the family doctor uses the computer (Electronic Medical Record).
3. If the doctor has to do a physical examination for the patient the research will leave the doctor's room.

Will the study hurt?

This study might make you feel uncomfortable because the researcher will be in the doctor's room during your visit with the doctor. You may feel uncomfortable when talking about your health with your doctor. This study will not physically hurt you.

Will you get better if you are in the study?

This study won't make you feel better or get well. But the doctors might find out something that will help other children like you later.

What if you have any questions?

You can ask questions any time, now or later. You can talk to the doctors, your family or someone else.

Here is the contact number and names of the study staff (researcher):

Who will know what I did in the study?

Any information you give to the study staff will be kept private (*or secret*). Your name will not be on any study paper and no one but the study staff and your family doctor will know that it was you who was in the study.

Do you have to be in the study?

You do not have to be in the study. No one will be mad at you if you don't want to do this. You will have the opportunity to decide whether or not you agree that a researcher observes your doctor's appointment.

If you don't want to be in this study, just say so. We will also ask your parents if they would like you to be in the study. Even if your parents want you to be in the study you can still say no. The doctor will still take care of your *state condition*.

Even if you say yes now you can change your mind later. It's up to you. The observation by researcher will not take place if I do not give consent.

Do you have any questions?

What questions do you have?

Assent

I want to take part in this study. I know I can change my mind at any time.

_____ Verbal assent given Yes □ No □

Print name of child

Written assent if the child chooses to sign the assent.

_____	**_____**	**_____**
Signature of Child	**Age**	**Date**

I confirm that I have explained the study to the participant to the extent compatible with the participants understanding, and that the participant has agreed to be in the study.

_____	**_____**	**_____**
Printed name of Person obtaining assent	**Signature of Person obtaining assent**	**Date**

Appendix D. Semi-structured interview guide

Interview Guide		
Interview questions	**Notes of participant's answers**	**Interviewer's guide to answers**
1. Could you tell me what type of model is this practice?		Traditional Fee For Service Family Health Group/Comprehensive Care Model Family Health Network/Family Health Organization AND NOT a Family Health Team Family Health Network/Family Health Organization AND a Family Health Team Health Centre (Community Health Centre/Aboriginal Health Centre) Nurse Practitioner Led Clinic Other
2. How long have you been using an EMR?		
3. Could you tell me what age category you are in?		A) Under 30; B) 30 – 40, C) 41 – 50, D) 51 – 60, E) 61 – 70, or F) 71 and older
A. Before the physician sees the patient		
4. How does the nurse notify the MD the patient is ready and the room the patient is located?		EMR feature (ex: In-office messaging) Face-to-face

		Whiteboard Chart in door Other
B. When the physician sees the patient		
5. Does the MD review the patient's chart prior to entering the patient's room?		[yes, no] If no, when is the patient's chart reviewed and where? If yes, where does the MD review the patient's chart? At the office At the nurses station Other
6. What information from the patient's chart does the MD review?		Lab tests Preventive/screening services that are due Problem list Medication list Clinical notes Can you explain any EMR features used?
7. What information does the MD enter into the patient chart when examining the patient?		Current blood pressure Plot/graph of the patient's history of blood pressure

		or a lab test Current weight Medical history Family history Where is this information documented? In the EMR? Which features are used? What type? Are customized templates used?
8. How do you know a patient is due or overdue for a test?		e.g., cancer screening, mammograms, Pap tests, blood tests, blood pressure/cholesterol measurement, vitamin supplements, etc. Who are the people or objects involved in this process? What EMR features are used? (ex: In-office messaging)
9. How do you diagnosis patients for chronic diseases?		Who are the people or objects involved in this process? Any EMR features used to help make the diagnosis?

		(e.g., plotting graphs of patient's history glucose/blood pressure/weight level)?
C. Patient Visit: Prescriptions		
10. How are in-office prescriptions written?		Prescription pads in room Prescription pads carried by doctor EMR/printer (with an option to select drug and dosage from a list) EMR and prescription sent directly to pharmacy (e-prescribing) If EMR features are used, please describe in detail which features and the processes.
11. Does the MD have a method to check for interactions/contraindications for medications? How does the MD do this?		Are EMR features used? Please describe in detail which features are used and the processes. Is a mobile app used? If yes, what type and how is it used?
12. How are prescriptions sent to the pharmacy?		Faxed Phone call

		Prescription printed and given to patient to pick up at pharmacy Prescription sent directly to pharmacy from EMR Are EMR features used? Which features? If prescriptions are directly sent to pharmacies from EMR, do you know how these pharmacies are linked with the EMR system at your clinic? (policies/protocols used?; Is it an in-clinic pharmacy?)
13. Describe the process when a patient asks for a refill during an office visit?		Who are the people or objects involved in this process? What are the inputs and outputs? What EMR features are used?
D. Patient Visit: Lab tests		
14. How are laboratory tests ordered?		Who are the people or objects involved in this process? What are the inputs and outputs? What EMR features are used?

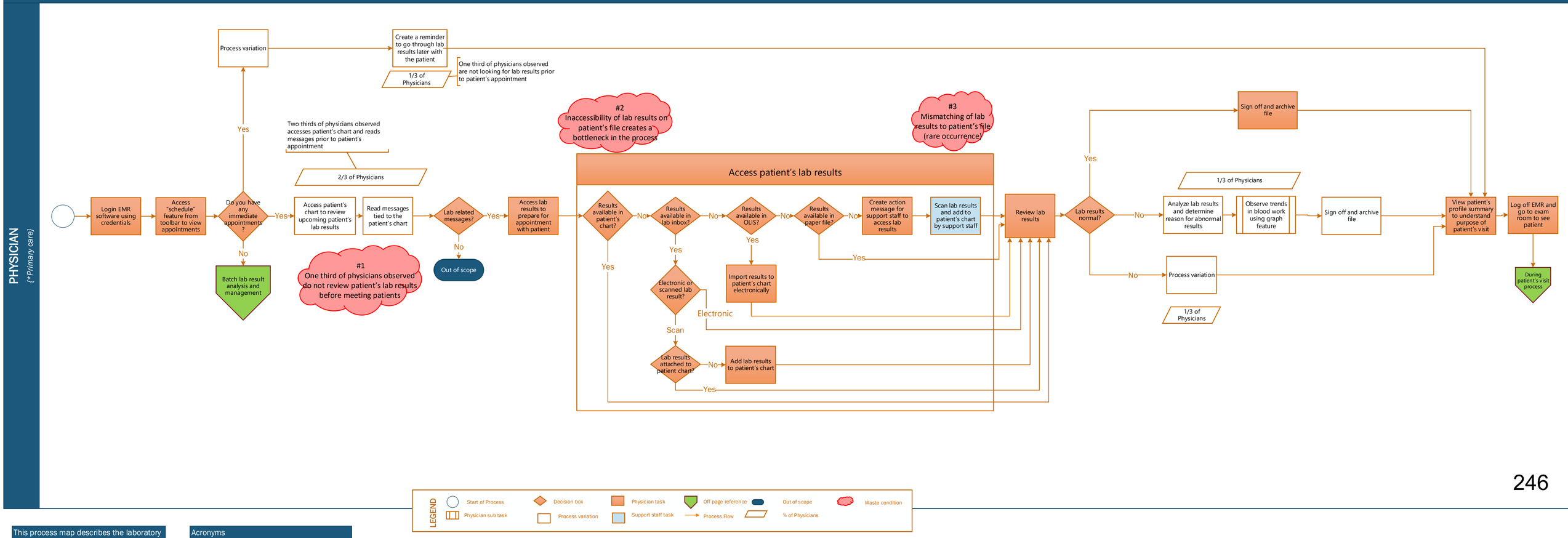
15. How are lab results returned to the clinic?		Who gets them? What do they do with them? How are they matched with the patient's chart? Who matches them? Any EMR features used?
16. Do lab results go to the patient?		How? Letter, phone call, email Any EMR features used?
17. Does the laboratory or hospital receive the orders directly from your EMR system?		If so, how are these laboratories/hospitals linked with the EMR system at your clinic? How is this process done? Do you know what policies/protocols are being used? If not, how does the laboratory or hospital receive the orders?
E. Patient Visit: Referrals		
18. Describe the ways patients obtain referrals?		Nurse/staff makes a call MD fills out form MD uses EMR and prints form to give to patient Any EMR features used?

19. How do you receive results of the referral? How do results get into the patient's chart?		Any EMR features used?
F. End of patient's visit		
20. When/where do you make your patient encounter notes (progress notes)?		In clinic In exam room Out of exam room At home, remote connect
21. How are progress notes documented?		Are EMR features used, which type of features?
22. How is billing handled? Please describe the process, the people involved.		Who documents the billings? Are EMR features used, which type of features?
Wrap Up:		
23. What do you like or dislike about your current EMR system when using it for CDPM?		Please provide examples.
24. Could you tell me how your use with the EMR for performing clinical tasks such as prescribing medication or ordering laboratory results has evolved from implementation to today?		(To account for the process of maturity factor)
25. Do you have an IT specialist that supports the EMR system at your practice?		IT specialists such as Quality Improvement Data Support Specialists (QIDSS)

26. Is the IT specialist funded by the government or by another source?		
27. Have you been using the same EMR software since implementation or have you or will you be switching to another version?		
In Conclusion…		
28. Do you have other comments or concerns about the use of EMRs for the prevention and management of patients with chronic diseases?		Anything else you want to say/comment on?

Appendix E. Current-State Workflow Diagrams Laboratory Results Management

Figure 1. PART I – PRIOR TO PATIENT'S VISIT – CURRENT STATE LAB RESULTS MANAGEMENT

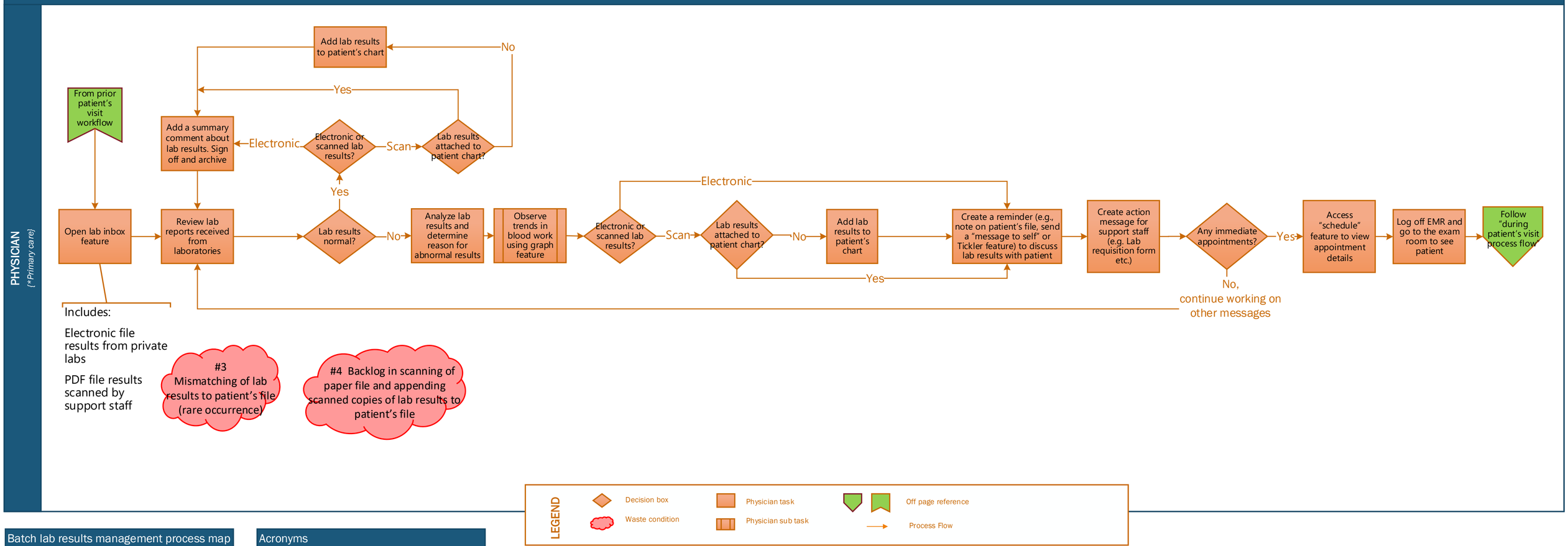


This process map describes the laboratory work related tasks performed by primary care physicians. These steps are carried out prior to patient's visit to prepare themselves for the appointment *(This observation does not include after clinical hours).*

Acronyms

EMR : Electronic Medical Records
OLIS: Ontario Laboratory Information System

Figure 2. PART II – PRIOR TO PATIENT'S VISIT – CURRENT STATE "BATCH" LAB RESULTS MANAGEMENT

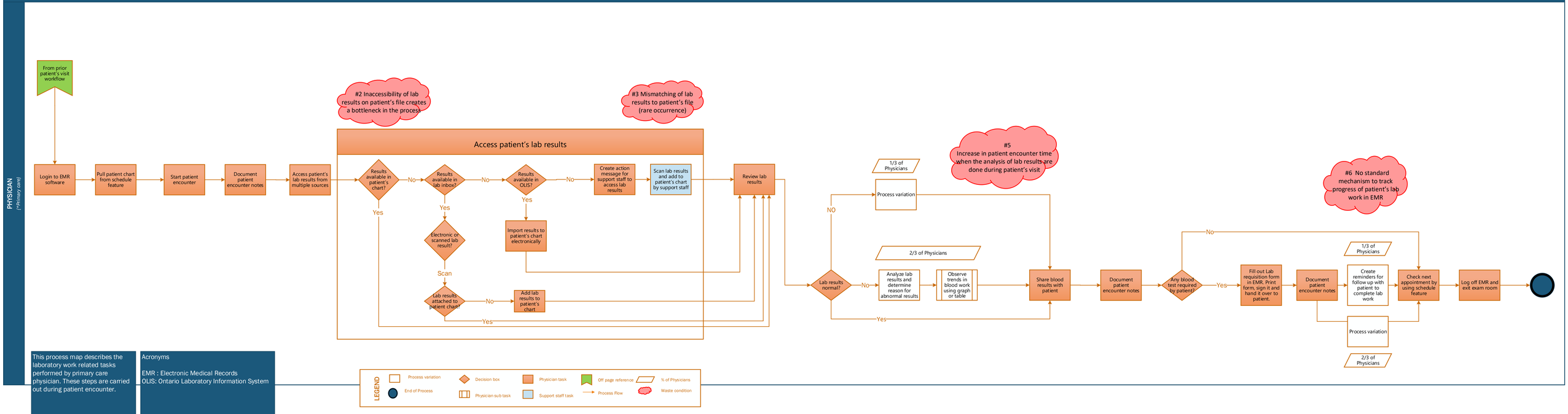


Batch lab results management process map describes the laboratory results analysis and management in lab inbox performed by primary care physicians. These steps can be carried out prior to patient's visit or when the physician is not taking appointments. *(This observation does not include after clinical hours).*

Acronyms

EMR: Electronic Medical Record
PDF: Portable Document Format

Figure 3. DURING PATIENT'S VISIT - CURRENT STATE LAB RESULTS MANAGEMENT



This process map describes the laboratory work related tasks performed by primary care physician. These steps are carried out during patient encounter.

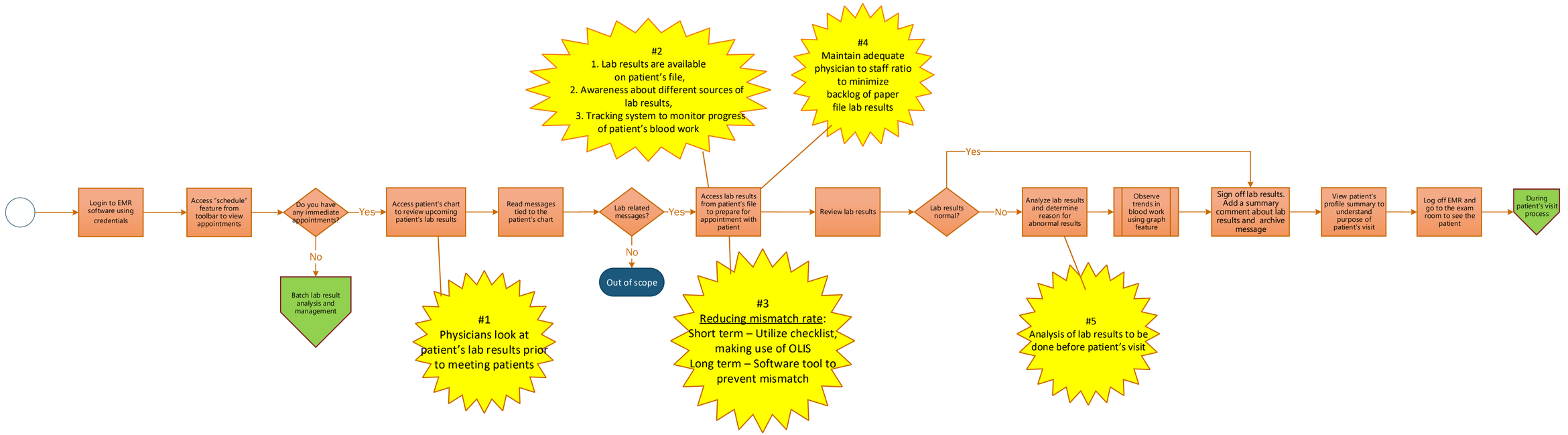
Acronyms

EMR : Electronic Medical Records
OLIS: Ontario Laboratory Information System

Appendix F. Future-State Workflow Diagrams Laboratory Results Management

Figure 4. PART I – PRIOR TO PATIENT'S VISIT – FUTURE STATE LAB RESULTS MANAGEMENT

PHYSICIAN
*(*Primary care)*



LEGEND

Start of Process | Decision box | Physician task | Off page reference | Out of scope

Physician sub task | Process Flow

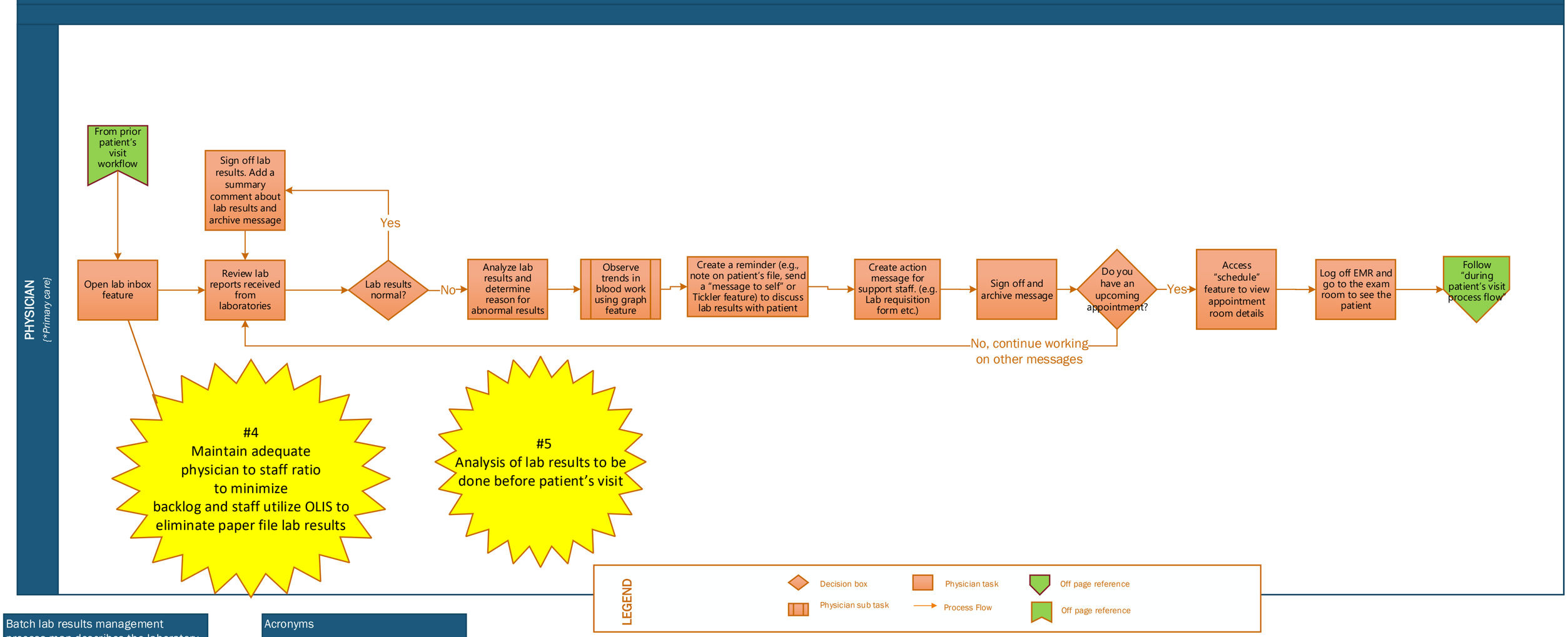
This process map describes the laboratory work related tasks performed by primary care physicians. These steps are carried out prior to patient's visit to prepare themselves for the appointment *(This observation does not include after clinical hours).*

Acronyms

EMR : Electronic Medical Records

Future state

Figure 5. PART II – PRIOR TO PATIENT'S VISIT – FUTURE STATE "BATCH" LAB RESULTS MANAGEMENT



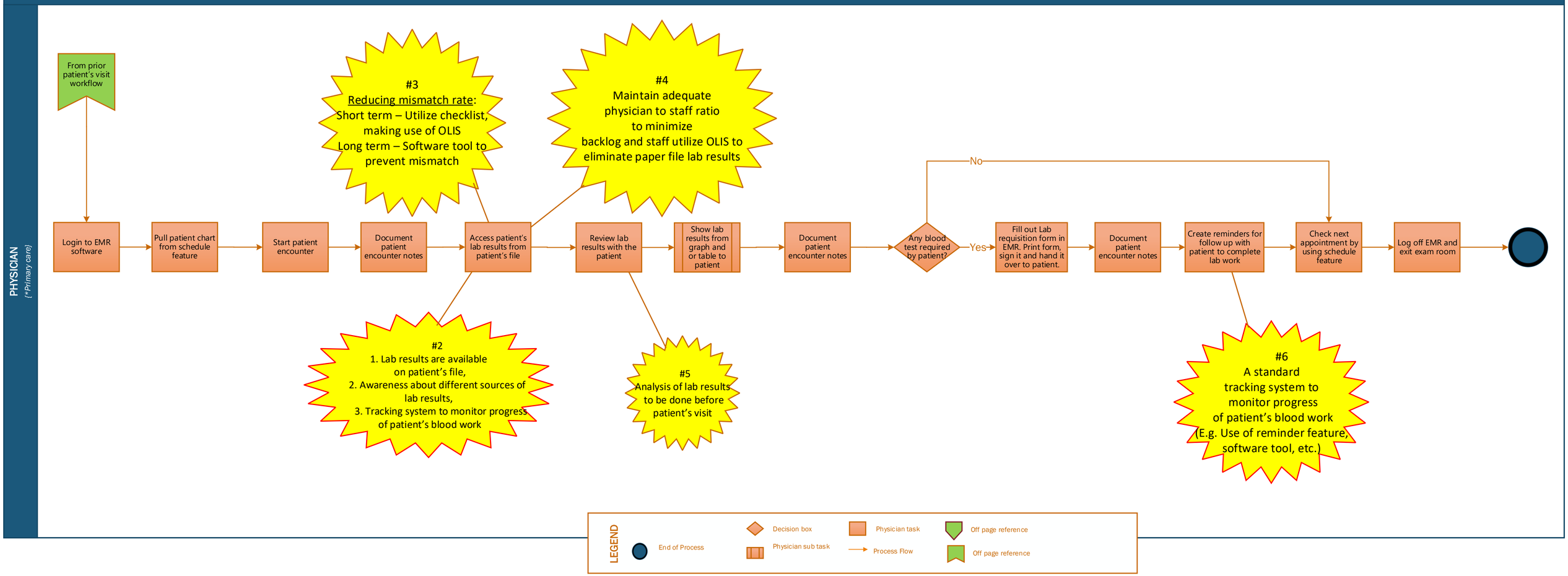
Batch lab results management process map describes the laboratory results analysis and management in lab inbox performed by primary care physician. These steps can be carried out prior to patient's visit or when the physician is not taking appointments. *(This observation does not includes after clinical hours)*

Acronyms

EMR : Electronic Medical Records

Future state

Figure 6. DURING PATIENT'S VISIT - FUTURE STATE LAB RESULTS MANAGEMENT



This process map describes the laboratory work related tasks performed by primary care physician. These steps are carried out during the patient's visit.

Acronyms

EMR : Electronic Medical Records
OLIS: Ontario Laboratory Information System

Future state