Investigating regional electronic information exchange as a measure of healthcare system integration: Making the invisible visible

by

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

BACKGROUND

Integrated healthcare systems are believed to be enabled by the electronic exchange of clinical information. Canada and other national health systems are making substantial investments in information technology, in order to liberate and share clinical information between providers, improve the quality and safety of care, and reduce costs, yet we currently have no way of measuring these information flows, nor of understanding whether they contribute to the integration of care delivery.

METHODS

A literature review and consensus development process (nominal group) were used to provide guidance on system integration measures which are enabled by electronic information exchange. In order to conceptualize the components of electronic information exchange, establish a reference vocabulary for terminology, and guide the development of a questionnaire to gather field data, a formal ontology was developed. Validation of a sub-group of the survey data quality was achieved using the ontology and an unrelated database, demonstrating how ontologies may be used to adapt performance measurement methodologies to systems where constraints such as time-compression, lack of resources or access to needed information are prevalent.

RESULTS

The survey tool gathered cross-sectoral data from a regional health system which populated a summary measure of inter-provider electronic health information exchange (the eHIE), and measured perceptions of system integration from a single health region. The eHIE indicated that 7 -12% of clinical information that could be shared, was being shared electronically in the health region. ANOVA confirmed a significant correlation between the amount of information being exchanged electronically in this system and respondent perceptions of system integration suggesting that the eHIE may be used as a leading indicator for healthcare system integration.

CONCLUSIONS

It is possible to conceptualize and quantify inter-provider electronic health information exchange. As complex adaptive systems, healthcare systems are dynamic and open to correction; the use of a leading or proximal indicator such as the eHIE may inform effective policy-making and resource allocation in our pursuit of the goal of seamlessly integrated care.

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This work is dedicated to the memory of my father, Mitchell Begley.

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Glossary

Term	**Definition**
Archetype	A recognized symbol or pattern of characteristics that can be assigned to a person, object or system such that others will recognize the symbol or pattern as representative of that person, object or system
Architecture	The set of organizational, management, and technical strategies and tactics used to ensure that an organization's systems have critical organizationally defined characteristics and capabilities (Glaser, 2002)
Clinical information	Clinical information refers to collected, stored or shared patient or population biomedical or demographic data, which is used in diagnosis, treatment or care management.
Class	In OWL, a class is a group of individuals which form a set as they can be described using one or more common properties
EDI	Electronic Data Interchange
eHealth	Describes "any healthcare practice supported by electronic processes and communication, including health information technology (HIT) and electronic health information exchanges (HIEs)"(K. Smith et al., 2008, p.viii)
eHIE	Electronic Health Information Exchange
EHR	Electronic Health Record (EHR) is a comprehensive electronic record of a patient's health and health care information from across the care continuum and time (Hoerbst & Ammenwerth, 2010)
Entity	An entity is a thing which exists independently
Health indicator	A "single measure" which can be expressed quantitatively to describe an important dimension of the healthcare system. Health indicators are typically used by organizations, policy makers or funders to measure strengths and gaps in system performance (Canadian Institute for Health Information, 2009, p.11)
Healthcare	Healthcare or the healthcare system is the aggregation of health services available to individuals for the diagnosis, treatment and prevention of disease, illness, injury or other physical or mental anomalies

Health care	Services provided to individuals by healthcare professionals which maintain or restore health
Health information exchange	The ability to exchange health information across organizations in a healthcare system
HIE	A Health Information Exchange (HIE) is an entity created to facilitate the exchange of electronic data amongst healthcare entities within a network, region or state
Health entity	A Health entity, for the purposes of this study, is any health care service provider or organization, governed by a single corporate body and delivering clinical care in one or more locations under one or more corporate names, to individual patients or groups of patients, and where the predominant funding is from public sources. A health entity might be a solo family physician, a laboratory with multiple locations, or a group of registered health professionals providing healthcare services in the community.
HL7	Health Level 7 (HL7) is an interface standard for exchanging and transferring health data between computer systems
IHE	Integrating the Health Enterprise (IHE) is a non-profit organization of users, developers, vendors, non-governmental and government representatives whose goal is to improve interoperability and information sharing between health information systems and healthcare entities, through common standards and technical profiles
Infostructure	"A shared foundation of hardware, software and communication technologies with associated architectures that enable an uninterrupted flow of [electronic] information" (Canada Health Infoway, 2006, p.7)
Integrated healthcare system	An integrated healthcare systems is one where providers and organizations from across the continuum of care work together to provide services in a seamless unified system for patients or clients
Interoperability	"The ability of two or more systems or components to exchange information and to use the information that has been exchanged" (Institute of Electronical and Electronics Engineers, 1990)
Legacy applications	An older technology application that continues to be used when there are newer versions or applications
Message	In the context of this study, message refers to information flows (sent or received) between health entities in a system
NHIN	Nationwide Health Information Network (NHIN) – "a network of

	networks built out of state and regional health information exchanges (HIEs) and other networks so as to support the exchange of health information by connecting these networks” (HIMSS, 2006)
Ontology	Describes the concepts or knowledge of a domain of interest and the relationships between those concepts (Horridge et al., 2009). Ontologies have been used to define a common vocabulary for those sharing information in a domain and have been used to develop standardized, structured vocabularies and coding systems such as SNOMED and the Unified Medical Language System to enable semantic interoperability between computer systems
OWL	OWL (Web Ontology Language) allows the meaning of information to be explicitly described through vocabularies and relationships in the form of an ontology or conceptual map which is machine interpretable
Properties	In OWL, properties are used to describe relationships between individuals, or classes, or from individuals to data values
RHIO	Regional Health Information Organizations (RHIO) – “a group of organizations and stakeholders that has come together for the purpose of electronic data exchange and is focused on improving the quality, safety, and efficiency of healthcare delivery” (HIMSS, 2006)

“Measuring, assessing, and reporting interoperability in a visible way
is essential to setting the right priorities…
developing and applying precise measurements… is difficult”

(Kasunic & Anderson, 2004)

Chapter 1

Introduction

Improving inter-organizational information exchange, making it faster, more accurate, more secure, and allowing users to capture information from different sources, facilitates care coordination (Ham & de Silva, 2009; Hoffmarcher, Oxley, & Rusticelli, 2007; Leatt, Pink, & Guerriere, 2000; Mercer, 2001), improvement in quality and reduced duration of care (Stiell, et al., 2003; van Walraven et al., 2008), increased accessibility (Durbin et al., 2001), cost reductions from fewer redundant medical procedures (Smith et al., 2008), reduced patient/client transfers (Hodge, 2008), and reductions in medical error rates (Schabetsberger et al., 2006).

Despite what some believe is a lack of robust evidence (Chaudhry et al., 2006) many consider information systems pivotal to the integration agenda (Brailer, 2005; Canadian Academy of Health Sciences, 2010; Ham & de Silva, 2009; Pederson & Leonard, 2005; Spragins & Lorenzetti, 2008; Suter, Oelke, Adair, Waddell, Armitage, & Huebner, 2007b) and that information sharing is a solution for the improvement and long term sustainability of healthcare systems (Armitage, Suter, Oelke, & Adair, 2009; Brailer, 2005; Grone & Garcia-Barbero, 2001; Suter, Oelke, Adair, & Armitage, 2009). Furthermore, many models of integrated care include a requirement for clinical information systems which facilitate information sharing between healthcare providers, for example the Chronic Care Model (Wagner et al., 2001).

A 2008 report published by the Commonwealth Fund identified six attributes of what experts described as an “ideal healthcare system” based on its demonstrated ability to drive high performance. The report explicitly identifies electronic exchange of “relevant clinical information” between appropriate providers as one of those attributes (Shih et al., 2008). Many studies have identified the need for free flowing clinical information between healthcare providers to improve the efficiency, safety and continuity of care delivery (Guthrie, Saultz, Freeman, & Haggerty, 2008; Ham, 2010; Kripalani et al., 2007; Shapiro, Kannry, Kushniruk, & Kuperman, 2007; van Walraven et al., 2008), others suggest that information and communication technology (ICT) is a key element in the liberation of those information flows (Fontaine, Ross, Zink, & Schilling, 2010; Georgeff, 2007; Gulavani & Kulkarni, 2010; Hollander & Prince, 2008; Institute of Medicine, 2001; Mercer, 2001; Mäenpää, Suominen, Asikainen, Maass, & Rostila, 2009; Rudin et al., 2011), yet none have expressly investigated the relationship between electronic health information exchange and system integration.

In one study of Medicare beneficiaries (those over 65 or with chronic illness) in the United States patient/clients saw over six unique physicians during 15 visits each year. Those with serious chronic diseases had almost 38 visits and saw 13 unique physicians in a year (Berenson & Horvath, 2002, pp.9). Any physician visit may initiate referrals or exchanges with numerous other healthcare services such as pharmacies, laboratories, hospitals, specialists, and imaging facilities; these in turn generate new information to be shared amongst health service providers who are increasingly urged to base clinical decision-making on evidence (Dykes & Bakken, 2004). Paper-based clinical information systems are practically limited in their ability to manage this volume of data and to support growing expectations of high quality, evidence-informed practice and team-based care. Yet ICT will do nothing more than digitally entrench information in the paper-based silos which characterize the current health system (Brailer, Augustinos, Evans, & Karp, 2003), unless they are designed for interoperability and the seamless exchange of relevant information to support effective clinical decision making.

All this appears intuitive, nevertheless adoption of technology and standards to support interoperability and electronic information sharing remains low in North America (Blumenthal, 2011;

Doebbeling, Chou, & Tierney, 2006; Klazinga, 2010; Marschollek et al., 2007). Many health systems have created initiatives to build national technology infrastructures (Ronchi & Khan, 2009). In Canada, sharing electronic information amongst health service providers lags the already slow adoption of digitized health records (Schoen et al., 2009). To date, over $2 billion has been invested by Canada's federal government (Canada Health Infoway, 2007; Webster, 2011a) and considerably more by provinces and individual healthcare organizations (such as hospitals, physicians, labs, long term care facilities and public health agencies).

While each receiving organization may be accountable to stakeholders for the impact of these investments, the only meaningful indicator of success is the amount of information flowing electronically between healthcare providers in a system of care. Kuziemsky & Weber-Jaknke (2009, p.135) suggest that there is limited accountability in the healthcare sector for interoperability projects and call for a framework for interoperability design that links various levels of the system from the micro (such as health entities) through to the macro (such as regional health systems).A system-level focus on performance measurement is consistent with the goals of integrated care (Grone & Garcia-Barbero, 2001). However there are currently no undisputed measureable outcomes of health system integration nor of health system interoperability, therefore no systematic ways to assess 1.) progress towards the goal of achieving a network of information systems which facilitate the exchange of patient/client information, and 2.) whether interoperability is contributing to the system's goal of seamless and integrated care.

Given that the risks of failure in electronically linking healthcare systems are assessed as "likely" and with a "very high" impact (Canada Health Infoway, 2010, p.31), there is clearly a need for accountability and measurement mechanisms to proactively manage an improvement agenda. Furthermore, the lack of a cross-sectoral report on healthcare interoperability and information exchange is particularly troublesome to governments (Commission on Systemic Interoperability, 2005).

This research study will generate a metric for electronic health information exchange, accounting for the different types of information appropriate for distribution, and how much, with whom and in what format it is shared. The relationship between this metric and system integration will be further examined.

1.1 Background

Healthcare in Canada is facing the prospect of a "perfect storm" brought about by shifting demographics, key health provider shortages, increasing prevalence of chronic diseases and their management costs, consumer demands for complete access to their health information and involvement in care decisions, fragmented healthcare services due to increasing specialization, concerns about quality and avoidable errors, and rising costs (R. Edwards, Ardal, & Butler, 2007; Organization for Economic Cooperation and Development, 2011; Snowdon & Cohen, 2011). In 2010 health expenditures were $193.1 billion in Canada[1]; over the period from 2006-2010 annual increases averaged 6.2 per cent and in 2011 and 2012 were expected to rise 3.9% and 3.4% respectively. The 2008-09 average total increase in expenditures for all governments (federal, provincial, territorial and local) was 2.5 per cent, yet combined revenues shrank by 2.1 per cent[2]. Clearly, "business as usual"

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[1] Statistics Canada. (2012). National Health Expenditure Trends, 1975 - 2012. Retrieved from https://secure.cihi.ca/free_products/NHEXTrendsReport2012EN.pdf September 9, 2013.

[2] Statistics Canada. (2009). Revenue sources and expenditures functions, consolidated governments. The Daily, June 16, 2009. Retrieved from http://www.statcan.gc.ca/daily-quotidien/090616/t090616a1-eng.htm. January 25, 2011.

has not addressed historic problems in the system and is unlikely to in the future. Innovations in care delivery are necessary to sustain current levels of service (Snowdon & Cohen, 2011).

While information technology adoption is unlikely to be sufficient to address these challenges, and the benefits of electronic information systems remain disputable though increasingly positive in the context of their use at full functionality (Black et al., 2011; Buntin, Burke, Hoaglin, & Blumenthal, 2011; Lau, Kuziemsky, Price, & Gardner, 2010), the balance of evidence suggests that electronically shared clinical information:

- Improves quality of care and outcomes (Bates et al., 1995; Chaudry et al., 2006; Craig, Callen, Marks, Saddik, & Bramley, 2007; Ontario Health Quality Council, 2010), particularly for patient/clients requiring chronic care (Health Council of Canada, 2009; Overhage, Evans, & Marchibroda, 2005);
- Improves patient transitions between care providers (Kripalani et al., 2007; Snow et al., 2009);
- May have the potential in the long term to reduce the total costs of care (Hripcsak, 2007; Ontario Health Quality Council, 2010; Walker et al., 2005);
- Reduces redundant clinical tests and procedures (Frisse & Holmes, 2007; O'Malley, Grossman, Cohen, Kemper, & Pham, 2010); and
- Averts medical errors (Bleich & Slack, 2009; Lau, Kuziemsky, Price, & Gardner, 2010; Singh, Naik, Rao, & Petersen, 2008).

For these reasons, many nations have created initiatives to build technical infrastructures in order to improve the flow of health information between providers, although North America’s efforts are relatively nascent in comparison to other jurisdictions such as the United Kingdom and Europe (Vest, 2012) . For instance, The United States’ National Health Information Network (NHIN), CONNECT and the Direct Project now provide the standards, services and software to enable health information exchange legislated by the American Recovery and Reinvestment Act of 2009 (The Office of the National Coordinator for Health Information Technology, 2009). However, initial requirements for electronic health information exchange remain quite modest.

In parallel with these efforts, experts and those responsible for the governance of healthcare systems have advocated for the integration of healthcare delivery believing it offers a solution to current cost and efficiency challenges, and future sustainability (Armitage, Suter, Oelke, & Adair, 2009; Shaw, Rosen, & Rumbold, 2011; The Ontario Health Services Restructuring Commission, 2000). Integration “is a process by which two or more entities establish linkages for the purpose of improving outcomes for needy people” (Konrad, 1996; Marquart & Konrad, 1996). Integrated health systems consist of multiple collaborators and “operate along numerous dimensions and at various levels of intensity, and encompass a variety of components, structures, and designs” (Konrad, 1996, p. 5). It is believed that integration:

- Improves quality of care (Raina et al., 2006);
- Supports more cost-effective care (Ahgren & Axelsson, 2005; Frisse et al., 2012; Hripcsak et al., 2007; Johri, Beland, & Bergman, 2003);
- Is an appropriate model as inpatient care declines in favour of community care (Conrad & Shortell, 1996; Lobach et al., 2007; Oelke et al., 2009); and
- Represents a possible response to the increasing complexity of care as chronic conditions grow and the population ages (Frolich et al., 2010; Glendinning, 2002).

Industry and academic discourse suggest that healthcare system integration and health information exchange are beneficial and tightly linked; yet there has been little theoretical or empirical support for these notions in the sector. Not surprisingly therefore, health system funders have struggled to identify system-level measures of integration and interoperability (Rosen et al., 2011, p.13) and thus are unlikely to be able to draw conclusions about their progress on either. Similarly, there has been little research in Ontario to document electronic information flows between care providers, nor to measure its impact on integration in regional healthcare systems.

1.2 Purpose

The purpose of this research is to

[1] Develop a theoretical framework to describe the relationship between electronic health information exchange (a measure of interoperability), and healthcare system integration;

[2] Propose a measure of electronic health information exchange (later referred to as eHIE);

[3] Develop a formalized conceptual map of regional eHIE, with explicate assumptions and properties associated with those conceptualizations to assist with validation of the eHIE; and

[4] Investigate the relationship between the eHIE measure and integration within the regional healthcare system.

1.3 Significance

Health sector spending represented 42.3% of Ontario's total provincial government expenses in 2011-12 ($46.5 billion of $109.8 billion)(Ontario Ministry of Finance, 2012). Unchecked healthcare expenditures are projected to account for 80% of total provincial program spending by 2030 (TD Economics, 2010). Ontario’s challenge is to provide more affordable care for an aging population living with chronic illness. In a system where medical advances demand increasing specialization and thus expanded circles of care, there is an inexorable imperative for efficient and “seamless” communication between healthcare providers (Hackl, Hoerbst, & Ammenwerth, 2011; Heale, 2011; McLeod, McMurray, Walker, Heckman, & Stolee, 2011). This seamless communication is posited as a remedy for chronic lapses in quality due to missing, late or un-communicated information. Moreover, it is referred to as a fundamental necessity for greater efficiency through integration, and consequently, sustainability of Ontario’s healthcare system. Information exchange is now rarely imagined both within and outside the healthcare system, without considering the ubiquity of new digital media to facilitate that exchange; yet we currently have no way of measuring these information flows, nor of understanding how they contribute to the integration of care delivery to patients/clients. Without measurement, management of priorities and resources is relegated to guesswork. Deriving an accurate and consistent understanding of electronic health information exchange concepts, and statistical evidence to link it with integration is critical for decision makers making evidence-informed choices about strategic allocation of resources and supportive policy to achieve seamless and coordinated delivery of healthcare services.

A systematic analysis of contemporary literature on electronic health information exchange and interoperability and their relationship with health integration has not previously been conducted, and is a necessary first step in order to conceptualize the interoperability/integration dyad. Also absent is a shared understanding and knowledge of the components of electronic health information exchange. This lack of shared understanding presents a significant barrier to measuring progress towards system interoperability and integration. A domain ontology, or visual representation of concepts, entities and the relationships between them, would establish that shared meaning and knowledge, and facilitate expert scrutiny.

Rapid and specific feedback loops improve performance (Tan & Wen, 2005). The work undertaken in this study has value for funding agencies, healthcare networks and stakeholders needing to understand and measure proximal outcomes of regional activities facilitating shared electronic health information to determine if they are “on the right track” (Lasker, Weiss, & Miller, 2001, p.183). The system-level measure developed here will contribute both conceptual and practical understanding of the factors contributing to electronic information exchange. The study will develop the foundations for a straightforward and inexpensive indicator which provides a relative ranking of health care entity’s clinical health information exchange activities. Collected data from individual health entities’ electronic information exchange activities will be aggregated and proposed as a leading system-level indicator of regional integration. The framework from which it is derived will establish a conceptual association between health care system integration and health information exchange; the indicator will provide empirical evidence of its validity.

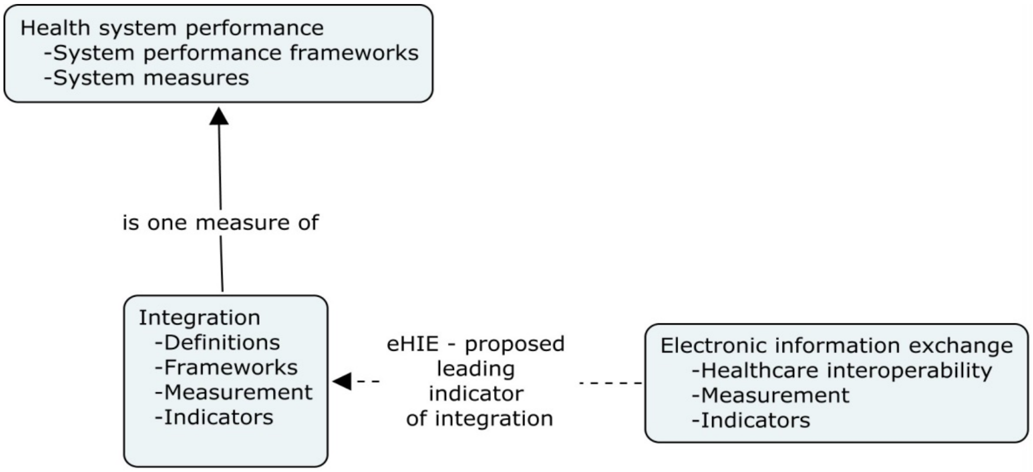
This measure will provide valuable feedback to policy makers, health system funders, and providers about the level of electronic information exchange and interoperability in Ontario’s mandated regional health networks. While individual sectors, particularly hospitals (Ontario Hospital Assocation, 2008a) and physicians (Ross, Schilling, Fernald, Davidson, & West, 2010) have reported on electronic information exchange in the past, this is the first study to measure the flow of electronic information and level of interoperability between health care entities across sectors in a health system; it will be the first to correlate this flow of information with progress towards health care integration

Chapter 2

Review of the Literature

The previous chapter introduced the imperative of electronic health information exchange to a high functioning healthcare system, and our inability to assess the extent of those information flows. Scant literature in the terminal area of research interest necessitates building this progressive corpus of knowledge in order to develop a focused understanding of the intersecting domains. This chapter examines the literature on system-level performance measurement, and then identifies frameworks and acceptable practice for the development of system-level measures. Next, a review of healthcare system integration, frameworks, key concepts and measures precedes an examination of the literature on inter-organizational electronic data exchange frameworks and metrics. Both contribute to the health system integration framework, and measure that was used in this study. A schematic of the domains of interest as they relate to these research objectives is provided in Figure 1.

Figure 1. Overview of the Literature Review & Domains of Interest



2.1 Healthcare System Performance Measurement

While far from a new concept patient outcomes data were being collected at the hospital of the University of Pennsylvania over 250 years ago (Loeb, 2004). Following that Florence Nightingale's work during the Crimean War in 19th century England uncovered the relationship between unsanitary conditions in hospitals and hospital morbidity and mortality. Since then much performance measurement activity in healthcare has occurred at the organization level in order to manage internal operations, or at global level in an effort to compare equity in access, cost, and comparison of national health and policy (Braveman, 2013; OECD, 2010). Following the lead of other sectors, multi-sectoral network measurement is of increasing interest as we understand healthcare as complex systems of systems whose agility and success is at least partially dependent on effective information systems (Rouse, 2007). The boundaries of what defines the health system have been redefined, with increasing evidence of the impact of non-medical determinants on individual and population health (Arah et al. 2005). This boundary "creep" has increased our understanding of the variables which might be considered when examining performance and their impact on outcomes, and contributed to the complexity that system-level performance presents to health researchers.

This complexity is multi-dimensional in nature and we have struggled with the challenges of developing measurement tools (Adair et al., 2003). First, many healthcare entities have difficulty identifying and measuring independent variables which contribute to outcomes. For instance, social service agencies may reasonably expect to be measured by their impact on societal wellbeing or hospitals by their influence on morbidity. Yet these outcomes are not always fully understood and a myriad of other variables impact their results. Second, the entity's objectives are rarely uncontested or simple, and as a result neither are the entity’s goals, leading to uncertainty around the dependent variable and further confounding of the previously mentioned problems of attribution (Freeman, 2002). Third, if intermediate outputs are used rather than outcome measures, there should be clear relationships between them, and finally, there is often a significant lag between an intervention and its impact. The recognition of these problems appears to cross models and jurisdictions if gauged by their appearance in publications from scholarly journals reviewed for this paper.

So while scientific evidence is important in the development of healthcare measures, when lacking it is often replaced by expert consensus (Sharom & Giacomazzo, 2011). In fact, some view stakeholder involvement in the determination of a system performance measurement process as critical to its credibility (Nathwani, Gray, & Borland, 2002; Watterson, 2004; World Health Organization, 2009). In fact, the most successful performance indicators are those for which there is a local sense of ownership and where stakeholders have been involved in their development (Busi & Bititci, 2006; Freeman, 2002; Veleva & Ellenbecker, 2001). In reality, many healthcare performance indicators are developed collectively within the context of a group or organization. Where differing perspectives and opinion on best practice complicate the performance indicator development and selection process, methods are used to gather and consolidate these views. In many cases, the very act of discussing measures forces experts to expose any differences of opinion or priorities (Neely et al., 2000).

Woolhandler and colleagues (2003) document a number of consensus techniques in common use such as the Delphi technique, nominal group technique and RAND appropriateness method (one form of a modified Delphi technique), confirming an identified theme from contemporary literature, that expert opinion is a pivotal component in the exploration and development of system performance indicators. Despite this normative approach, there are a number of system performance frameworks which have helped guide the development of measurement systems and indicators, and which contributed to the development of the framework for this project. These frameworks will be briefly reviewed.

2.1.1 System Performance Frameworks

Kaufman and colleagues (2006) describe a framework as a collection of concepts or ideas that guide research and theory development. Frameworks are valuable in exploratory investigations helping to conceptualize the dimensions of performance and guide the selection of indicators. The most commonly applied frameworks for healthcare system performance include the balanced scorecard (BSC) and Donabedian's structure-process-outcomes (SPO) model. The determinants of health model (Arah, Klazinga, Delnoij, Asbroek, & Custers, 2003; Leatt et al., 2000; Tawfik-Shukor, Klazinga, & Arah, 2007) is primarily used in the evaluation of national health systems, focusing on both a medical and non-medical evaluation of factors contribution to population wellness.

The BSC's four perspectives of performance in the business domain – financial, customer, internal business processes, and learning and growth – moves evaluation of organizations away from a singular focus on finances, captures various stakeholder interests, and incorporates both short and long-term objectives (Kaplan & Norton, 1992). When used in the healthcare domain, the perspectives may be modified to better represent relevant categories, such as "health determinants and status", "community engagement", "resources and services", and "integration and responsiveness" (Woodward et al., 2004 as cited in Etches, Frank, Ruggiero, & Manuel, 2006). While the BSC was developed to measure organizational performance it has been successfully used to measure system-level performance (Hansen et al., 2008; ten Asbroek et al., 2004).

The BSC also strongly advocates for the use of indicators which both measure key performance drivers (leading indicators), as well as those which measure outcomes (lagging indicators). It is this explicit requirement for a mixture of both leading and lagging indicators in system performance measurement which is of particular interest to this study. The importance of leading indicators is their capacity for measurement of interim or proximal goals, such as interoperability, which allows for mid-course correction in support of longer term goals such as integration of healthcare delivery.

Donabedian's SPO model is built on the notion that healthcare quality can be inferred from the measurement of three components: structures, processes and outcomes, and that measurement is possible whether at the patient, organizational or system level, using this framework (Donabedian, 1988). He infers that health entities' performance in a healthcare system can be aggregated to measure system-level outcomes, and that the causal links between good structure and processes, good processes and good outcomes must be theorized and understood prior to measurement (Donabedian, 1988). In practice it is common for system performance measurement frameworks to be built on one or more combinations of the models previously described.

2.1.2 System Performance Measures

The organized collection and sharing of healthcare system performance data is now common and supported by an active international community of researchers (McKee, 2010). Although many approaches continue to focus on measuring the processes and outcomes of specific health encounters, or organizations, the literature reveals a couple of important trends in the development of system-level measures.

First, there is broad interest in reporting and monitoring performance using summary or composite indicators that combine multiple measures into a single index. Summary indicators reduce the information burden for users, but have been criticized for their inability to a) disaggregate into micro and meso indicators which allow policy makers to identify levers for decision-making and improvement; b) monitor progress related to sub-population groups; and c) isolate the impact of interventions (Field and Gold 1998; OECD 2002). In other words, many summary indicators help identify good or poor performance, but do not assist managers and policy-makers in diagnosing the causes of success or failure. The development of summary indicators that are explicit aggregations of theoretically and empirically linked causal factors would address these limitations by enabling an 'unpacking' of the summary indicator into specific actionable opportunities for improvement.

One such indicator is the Technology Achievement Index (TAI) a summary indicator developed by the United Nations to quantify the capacity of nations to leverage new technology and innovations (UNDP, 2001). In the aggregate it allows for comparison between nations and is comprised of outcome indicators from four dimensions that were designed for a broad range of respondent countries. The index is a simple, non-weighted, arithmetic average related to the creation and diffusion of technologies and human skills development that allows comparison between nations. For example, explore the contributing indicators from 2001 and one finds that diffusion of old technology (such as electricity and phone technology) and education in the sciences is poorly dispersed in Brazil. Mexico fares relatively poorly on the same indicators but has been highly successful in exporting technology-based products and thus has a high relative overall TAI (Desai, Fukuda-Parr, Johansson, & Sagasti, 2002). Examining progress on the dimension indicators allows countries to track the performance of policy and resource investments over time, and their relative impact on TAI rankings (Nasir, Ali, Shahdin, & Rahman, 2011).

Secondly, there is an increasing focus on measures of healthcare integration (Strandberg-Larsen & Krasnik, 2009). Rush and Nadeau (2011) distinguish between service-level and system-level integration of care. The latter focuses on policy, resource allocation, governance, leadership and management, and supports the former, service-level integration, which the patient or client experiences as continuous care from collaborating healthcare providers. Both perspectives must be accounted for in emerging measurement schema, however are unlikely to be captured in one summary measure and for this reason we focus here on system-level integration from the providers' perspective.

Past paradigms of provider-specific performance reporting are gradually being considered insufficient in healthcare. As a complex, adaptive system, healthcare system measurement requires a systems perspective (Plsek & Greenhalgh, 2001) that uses methods which are understandable and meaningful to stakeholder groups who are also engaged in their development (Hilarion et al. 2009). To better understand the concept of healthcare system integration and its role in healthcare quality and sustainability, the following section identifies explanatory frameworks, deconstructs the concept and what we know about its measurement.

2.2 Healthcare System Integration

In the first part of the twentieth century, non-medical factors such as housing and sanitation played a significant role in health outcomes and mortality (Bunker, 1995).While they remain significant, mortality from infectious diseases is diminishing and morbidity associated with individuals' and populations' risk of and experience with chronic disease is on the ascendance. With that, access to and the coordination of health services from prevention to treatment, have become increasingly important to individual's mortality and quality of life (Kelly et al., 2009).

Yet, current models for healthcare delivery in Canada remain siloed by sector and funding, and have not, for the most part, been reorganized around a framework for chronic disease. So for example, global funding models incent hospitals to discharge hip fracture patients early, yet funding for home care rehabilitation services such as occupation therapy and physiotherapy are highly variable across the province and have been decreasing since 2008 despite the aging population (Armstrong, 2013). These arbitrary distinctions between provider and setting have tended to result in fragmented care rather than care centred on the patient or client, and integrated across the continuum of care (The Change Foundation, 2010a). Perverse outcomes such as these, which emanate from obsolescent healthcare models, have helped focus the attention of policy makers on improvements which would encourage greater coordination and continuity of care delivery, particularly amongst regional networks of providers.

The focus on “inter-organizational networks at the network level” that is implied by integration, is an area which Provan and colleagues (2007) describe as under-researched. Further, there is an even more limited body of literature on the system-level measurement of healthcare integration. Strandberg-Larsen and Krasnik (2009) identified 24 methods for measuring broadly defined healthcare integration, but noted that the field remains embryonic and that measures are highly contextual thus limited in their use. System integration is derived from organizational and systems theory (Lawrence & Lorsch, 1967) that suggests organizations specialize in response to environmental uncertainty but in doing so became less integrated with other organizations in the system.. However, differentiating out risk creates inefficient and ineffective systems (Kodner & Spreeuwenberg, 2002; Shigayeva, Atun, McKee, & Coker, 2010). To balance these competing needs, systems look for coordination through integration, an approach which connects organizations and networks through combinations of funding, administrative, organizational, service level and clinical strategies (Kodner & Spreeuwenberg, 2002).

North America and Europe have a long history of interest in the integration of health services as a tool to improve continuity, care coordination, efficiency and quality (Marquart & Konrad, 1996; Suter, Oelke, Adair, Waddell, Armitage, & Huebner, 2007a). During the 1990's U.S. health delivery organizations rushed to coordinate providers under common structures or organizations using a combination of vertical (such as organized delivery systems from hospitals to primary care practices) and horizontal (such as multi-hospital systems) integration models (Devers et al., 1994). Many failed and others reversed their trajectory towards integration favouring instead to operate more loosely bound partnerships (Burns & Pauly, 2002; Dubbs, Bazzoli, Shortell, & Kralovec, 2004). Others such as Kaiser Permanente, Veteran's Affairs and InterMountain Health have improved their productivity and quality of care, attributing much of their success to their integration and innovative use of information technology (Shortell & Kaluzny, 2005). For these models, both vertical and horizontal integration of services generally involve organizational mergers and consolidation of ownership.

In other cases, integration speaks less to ownership than it does to policy, governance, processes and structures which help care providers deliver seamless care across organizational and disciplinary boundaries (Rosen et al., 2011). Both types of integrated systems however, share the goal of clinically integrating providers within a region, and optimally moving toward a shared ideology and coordinated clinical approach to patient/client care. Recently, new forms of organizational structures such as GP Commissioning Consortia (Shaw et al., 2011) and health and wellbeing boards in the United Kingdom (Humphries & Curry, 2011), and accountable care organizations in the United States (Shortell, Casalino, & Fisher, 2010), have attempted to improve the coordination of care between entities delivering healthcare services.

Yet no one integration model has emerged as dominant and the degree to which integration is embraced appears linked to the regulatory environment, health system funding models, governance, historical precedence and professional relations. It is this heterogeneous blend of factors which makes it difficult to measure an “optimal” level of integration within a health system, and which points to successful integration being highly contextual and perhaps, therefore, appropriately defined by those participating in the system.

Some discourse on integration reveals fewer concerns about mergers and organizational consolidation, and pays more attention to what amounts to virtual integration of independent entities or integration involving collaborative and cooperative relationships between providers with minimal joint corporate oversight and loose linkages between actors in the network (Lamarche et al., 2003). As with all integrated systems however, clinical and fiscal responsibility for a specific population inevitably leads to some consolidation of services. This is indeed the case in many provinces in Canada which have chosen to deliver disease- and population-specific services via networks of specialized care with central governance, specific funding mechanisms, interdisciplinary teams, cross-sectoral care, and outcomes accountability. Cancer Care Ontario is an example of such a virtually integrated organization. In the same way, virtual health networks are the predominant regional integrating mechanism across the provinces for healthcare oversight; for instance the Local Health Integration Networks in Ontario and Regional Health Authorities in British Columbia (at the time of writing all territories, PEI and Alberta retain centralized rather than regional systems).

In order to propose a theoretical framework that encompasses all the dimensions of this research study, we need to acknowledge the ambiguity about what healthcare system integration entails. To propose a theoretical framework relating electronic health information exchange to integration, the following sections will define the integration construct for our purposes, and examine integration frameworks and measurement models.

2.2.1 Definitions

The notion of definitional ambiguity surrounding integration has been well documented in the literature (Goodwin, 2013; Kodner & Spreeuwenberg, 2002; Kodner, 2009; Macadam, 2008; Suter et al., 2009) and prompted Howarth & Haigh (2007, p.1) to refer to it as an "academic quagmire of definitions and concept analyses". Not surprisingly therefore, there are no consistent or standardized definitions of integration in the health domain (Evashwick & Aaronson, 2006; Kodner, 2009), and it is interpreted differently by different disciplines (Shigayeva et al., 2010).

Grone & Garcia-Barbero (2001, p.7) note that the World Health Organization's European Office for Integrated Healthcare Services supports the following definition which presents integration as the corollary to integrated care:

> "*Integrated care* is a concept bringing together inputs, delivery, management and organization of services related to diagnosis, treatment, care, rehabilitation and health promotion. *Integration* is a means to improve the services in relation to access, quality, user satisfaction and efficiency" (author's initials).

This is an important distinction. Integrated care is necessary for system integration, but is not sufficient; whereas in an integrated system one would expect to find integrated care (which might be referred to as coordinated care, collaborative care, seamless care, or some other synonym). Thus, system integration is believed to occur as a result of a number of different factors, once of which is integrated care.

Raina et al. (2006, pp. 2-3) reported two definitions of system integration in use by the Ontario Ministry of Health and Long Term Care. The first by their Health Results Team for Information Management defines the system and its outcomes:

> "An integrated health system would result in coordinated health services that both improve accessibility and allow people to move more easily through the care and treatment continuum of the health system and provide appropriate, effective and efficient health services."

The second, by their Local Health Integration Network (LHIN) team defines the processes of integration related to specific outcomes:

> "Integration is defined broadly to encompass the process of effectively managing the alignment of multiple systems of independent (and interdependent) organizations with unique goals and objectives to achieve three important outcomes that are central to the Ministry's transformation agenda:
>
> - Ensuring that users experience services as seamless, where boundaries between organizations are not apparent to them;
> - Improving the match between single services provided and the multiple needs of clients and families;
> - Enabling effective and efficient use of system resources and capacity by optimizing system interactions across the system and across program silos."

Suter et al.'s (2007a) systematic review of the health and business literature yielded 175 definitions of integration and described a domain rife with terminology such as “collaborative care”, “shared care” and “coordinated care”, which is used interchangeably to describe the construct or components of integration. Despite the ostensibly interchangeable nature of these terms, each has emerged from different care contexts; while descriptive of components of an integrated system, they do not encapsulate the sense of collective and common, system-wide purpose inherent in healthcare system integration. All terminology, however, evokes the necessity for information sharing and the free flow of patient data between providers in a patient's continuum of care.

Suter et al.(2007, p.5) suggest that a 2006 definition provided by the organization now known as Accreditation Canada is inclusive of all analogous terms:

> "Services, providers, and organizations from across the continuum working together so that services are complementary, coordinated, in a seamless unified system, with continuity for the client".

The polymorphic nature of integration, the different instances it describes and contexts in which it is used, suggests that finding an overarching definition which captures most if not all occurrences but has more detail or specificity, is unlikely. For this research study a definition which is inclusive, outcomes focused, and understood by a wide variety of providers across different healthcare settings is required, one that incorporates common definitional components such as the alliances between providers and organizations within the system, a patient/client focused approach and the provision of seamless care. It will focus on integrated and seamless care as an outcome of system integration. The Accreditation Canada definition is used therefore as a base, with adjustments made for the perspectives of a range of health entities within a regional health system (as these are the intended respondents for this research study), and is used forthwith:

> "An integrated healthcare system is one where providers and organizations from across the continuum of care work together to provide services in a seamless unified system for patients or clients".

2.2.2 Health integration frameworks

Consistent with the lack of a common definition of integration, there are no uniform conceptual models of integration in the health literature (Suter et al., 2007; Valentijn, Schepman, Opheij, & Bruijnzeels, 2013) and a lack of a “sound paradigm through which to examine the process” (Goodwin, 6, Peck, Freeman, & Posaner, 2004). Shigayeva and colleagues' (2010) review yielded 40 different analytic frameworks. From the chronic care literature a number of established frameworks have been used to provide integrated care to those living with long-term conditions. Sing & Ham's (2006) review of broad international frameworks identified the Chronic Care Model (Wagner et al., 2001), the Expanded Chronic Care Model (Ministry of Health Planning, 2003), and the Innovative Care for Chronic Conditions Framework (World Health Organization, 2002). While there is some evidence that individual components of these models may impact quality of care and some other outcomes, there is a shortage of high quality evaluative studies to empirically support the entire framework nor substantial components of it. The growing importance of chronic disease in the overall burden of ill health internationally, suggests that these models are worth noting; however, while they have a comprehensive list of components, they are more suited to their intended special population than as a framework for integration at a system level.

More general integration frameworks have developed over the last two decades. The first wave of frameworks were modeled after Shortell and colleagues' early conceptions which focused on structural components of integrated service delivery (1993;1994), and were driven primarily by economic constraints (Strandberg-Larsen & Krasnik, 2009). Those early models, which place information systems at the nexus of a system of health service providers (such as home care, hospitals, nursing homes, primary care providers and specialists), have a network governance mechanism coordinating the system (this may be a corporate owner, publicly-funded coordinating organization, or an alliance or partnership), and generally require a defined population and supportive funding mechanisms.

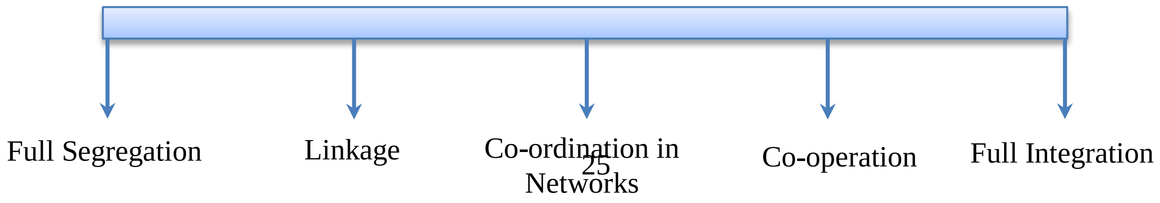
Shortell et al. (1994) identified three discrete requirements which contribute to the achievement of integration. First, clinical integration is the extent to which patient care services are coordinated across the system, and is a necessary but not sufficient component of integration (without clinical integration full integration is impossible). Second, functional integration refers to operations that support care coordination (such as information management, financial management and strategic planning), and finally physician-system integration (also known as professional integration) refers to the degree that physicians actively endorse and engage in the system and its governance. Not surprisingly, functional integration with its more predictable and transactional character is viewed as easier to achieve than physician/service or clinical integration (Shortell & Hull, 1996). These three “types” of integration appear elsewhere in the literature (Armitage et al., 2009; Van Deusen Lukas et al., 2002), as do references to instances of integration lying on a continuum of overall integration, depending on their levels of clinical, functional and physician-system integration (Leatt et al., 2000).

More recent frameworks or models are multi-dimensional, comprehensive constructs which include not only the structural components of an integrated system, but also the functions and processes which bind those elements together. As with the earlier models, these later comprehensive approaches exist on a continuum; from an integrated system where the providers pool finance, compete for contracts, share information systems and assessments, and work in multidisciplinary teams which coordinate care, to systems where they have few to none of these integrating features (Kodner & Spreeuwenberg, 2002; Leutz, 2005; Shigayeva et al., 2010; Valentijn et al., 2013). Interest in expanding the boundaries of health system integration models to include social care systems is growing (Cameron, Lart, Bostock, & Coomber, 2013; Humphries & Curry, 2011; Shaw et al., 2011) though with mixed results. This move to integrate health and social services is likely due to the increasing popularity of population-based funding models (Deber, Hollander, & Jacobs, 2008), the growing interest in expanding the scope of health system performance measurement to include the broader determinants of health (Arah, Westert, Hurst, & Klazinga, 2006), and the need for drastic reductions in public spending on health and wellbeing in some jurisdictions (Glasby, 2010; Ham & de Silva, 2009; Ham & Smith, 2010).

These broader frameworks lie outside the scope of this research project. However, boundaries between healthcare and social support are fuzzy in most systems including Ontario (despite the apparent separation of funding, policy, and governance mechanisms). This will manifest itself later in this research study's regional Ontario survey sample which, while it specifically excluded non-clinical entities in the social services, includes entities whose roles lie on the cusp of health and social care, for example the community care access centres.

There are a number of common components to frameworks of an integrated system which contribute to its placement along a continuum from completely segregated to fully integrated (Ahgren & Axelsson, 2005) (see Figure 2). The likelihood of having a completely segregated system equivalent to a closed system, is unlikely; likewise a completely integrated system is both unlikely and of questionable value (Leatt et al., 2000; Shigayeva et al., 2010).

Figure 2. Continuum of Integration (Ahgren & Axelsson, 2005)



Drawing on empirical and theoretical literature some researchers believe that integration is a "nested" concept suggesting a hierarchical structure (Kodner, 2009, p. 11; Macadam, 2008, p. 2) but disagree on the details of the classification system for its component parts. Macadam (2008) refers to "types" (linkage, coordination, and full integration), "levels" (system, organizational and clinical), and "forms" (vertical and horizontal). Kodner (2009) on the other hand uses similar labels and concepts but differing combinations to describe "foci" (entire communities or rostered populations, vulnerable sub-groups, and patient/clients with complex illnesses), "types" (functional, organizational, professional, service or clinical, normative, and systemic), "levels" (funding, administrative, organizational, service delivery, and clinical), "breadth" (horizontal and vertical), and "degree" (linkage, coordination, and full integration). Similar constructs are identified by Rosen et al. (2011) whose equivalent of levels is referred to as "groups of integrative processes" that are "clinical", "informational", "organizational", "financial", "administrative", and "normative".

Suter and colleagues (2007), in their comprehensive review of the health and business system integration literature, choose to organize the models in their literature review by levels referred to as "system", "progressive or sequential", and "program/service". System level models are those which attempt integration amongst many components and levels of a network of organizations. Progressive or sequential models focus on integration across the continuum of care with a progressively higher level of integrated care based on the needs of the individual or population being served. An example of this is Boon and colleague's (2004) model of integrative "team healthcare practice" outlining care that runs from parallel approaches characterized by independent healthcare practitioners acting alone, to integrative systems with interdisciplinary teams treating patient/clients collaboratively.

Program/service level models focus on integrating mechanisms closest to the individual such as case management.

Shaw and colleagues (2011; p. 9) avoid the use of a hierarchical structure saying “there is no hierarchy of integrative processes”. They refer to “systemic”, “normative”, “organizational”, “administrative”, and “clinical” integration merely as types of integration explaining that they may be more or less prominent depending on the circumstance in which it is used and on the level of vertical, horizontal or virtual integration desired; this approach is consistent with others who also classify integration initiatives as “macro” (governance and policy arrangement which promote integration at a systems level, “meso” (activities which promote inter-organizational cooperation), and “micro” (activities which promote integrative care amongst individual practitioners) (Cumming, 2011; Curry & Ham, 2010; Fulop, Mowlem, & Edwards, 2005). This approach may be useful on one level, but does not help to explain the important associations between types of integration which is necessary when developing and understanding evaluation schema.

Valentijn and colleagues (2013) refer to macro (system), meso (organizational and professional), and micro (clinical) integration that is facilitated by functional and normative integration. They link this model to person-focussed and population base primary care, hoping to test causal relationships between integration levels. The success of this model has yet to be confirmed, however its lack of conceptual connection between integration and healthcare system outcomes, such as seamless care suggest that it will require modification if it is to contribute to our understanding of causation.

Kodner & Spreeuwenberg (2002) refer to a continuum of integrated care “strategies” which include categories such as “funding”, “administrative”, “organizational”, “service delivery”, and “clinical”. Suter and colleagues (2009) created an anthology of functions rather develop an integration framework or model. Their “universal principles” for successful integrated healthcare systems” are constructed from shared characteristics supported by industry experts and contemporary literature (Figure 3), and combine both functional/structural and process/behavioural constructs.

Figure 3. Universal Principles of System Integration (Suter et al., 2009)

1. Comprehensive, seamless services across the care continuum
2. A patient centric approach including partnerships in care with patients and their informal caregivers
3. A population-based approach using geographic rostering
4. Shared standards and protocols delivered through inter-disciplinary teams
5. Multi-level performance measurement and management
6. Accessible and interoperable electronic information systems for exchange of financial, administrative and clinical data
7. Leadership to develop and overcome inter-disciplinary conflict and cultural differences
8. Alignment and leadership of physicians towards integration goals
9. Multi-stakeholder governance structures and organizational design which is responsive to the environment and accountable
10. Sound financial models and management

Others have suggested similar lists of factors which are key to success in integrated systems such as culture, information systems, physician leadership, clinical integration and inter-disciplinary practices (for example Shaw et al., 2011). In Rosen et al.'s (2011) model, integrating processes are enabled by skilled leadership, consistent communication and high-trust relationships. Leatt et al.'s (2000) criteria for an integrated health network remain relevant and include a patient/client-centred focus, effective communication and exchange of clinical information to avoid duplication such as having to repeat symptoms and history of care at each encounter, having sufficient information to make informed choices, coordination between primary care providers and others in the circle of care, and proactive management of information to facilitate preventive and self-managed care related to chronic illness. Emerging models in Canada invoke systems theory and choose not to focus on administrative and governance distinctions but rather on integration at the service level to ensure that the focus is on patients/clients who should experience seamless care (Rush & Nadeau, 2011).

Most of the integration frameworks reviewed above address the “what” of system integration and attempt to categorize the type and level of integration (Kodner & Spreeuwenberg 2002; Shigayeva et al., 2010). Other frameworks focus more on implementing or delivering integrated care, and emphasize the processes or the “how” of system integration, still others attempt to create integration frameworks which incorporate the patient/client perspective missing in many integration models (Humphries & Curry, 2011; Humphries & Gregory, 2010).

The Change Foundation’s Critical Elements of Integrated Care framework (The Change Foundation, 2009) includes: the patient perspective, provision of care using multi-disciplinary teams, governance structures and funding models that acknowledge regional shared risk, quality improvement through managed performance, and information system coordination. While worthy of mention given its origin in Ontario, simplicity, and usefulness in highlighting key elements of system integration, the framework’s focus on processes and structures does not easily allow comparison of outcomes with a system’s integration architecture. Moreover, it does not reference previously published literature in the domain which would help situate the new framework in the context of what has gone before.

It is clear that a common meta-framework and consistent use of terminology would advance this domain (Stein & Rieder, 2009) and would be particularly useful to policy makers wishing to gauge progress towards integration. A summary measure must be easily deconstructed into its component parts as mentioned in Section 2.1.2., and thus a conceptual framework with clear theoretical links between inputs, processes and outcomes lays the foundation for empirical research to validate those links. The lack of current consensus on definitions and models of integrated healthcare has impacted policy makers' and funders' ability to accurately measure the construct. Moreover, researchers have struggled to find accurate and reliable measures and indicators for system-level integration for which data are available or easily accessible (Armitage et al., 2009; Suter et al., 2007). In order to establish the link between inter-organizational electronic health information exchange and system integration a clear theoretical model of integration and the components of interoperability must be established. From this foundation, appropriate measures may be derived. In the next section we review the small but growing body of literature on the measurement of integrated healthcare delivery systems (Shaw et al., 2011).

2.2.3 Measurement of Healthcare System Integration

Strandberg-Larsen and Krasnik (2009) identified 24 methods for measuring structural, cultural and process measures of integration, but noted that the field remains embryonic and measures highly contextual, suggesting the need for specific tools with which to evaluate performance. Any method of evaluation must accommodate complexity derived from the multiplicity of organizations, providers and levels of delivery which are included in a healthcare system, and is confounded by issues such as the previously demonstrated definitional fuzziness, the diverse perspectives of the participants, and difficulty identifying discrete variables when attributing cause (Armitage et al., 2009). Therefore, evaluation of system integration necessitates stakeholder involvement in the process and as such will be influenced by socio-political factors which may impact methodology and research design.

While some literature suggests that integration might be treated as an end in itself, and refers to measures of "implementation" (Armitage et al., 2009) suggesting a defined end-product, there are others who suggest that integration is ongoing and a means to quality care improvement, rather than end until itself (Humphries & Curry, 2011; Stein & Rieder, 2009). The majority of literature examined supports the latter view; that the dynamic nature of healthcare systems makes for fluid boundaries and roles. Thus system-level measurement of integration, should occur across boundaries and continua of care (Adair et al., 2005), is likely best be considered over multiple time periods (Armitage et al., 2009), and should retain some flexibility to accommodate changing health system goals (Rush & Nadeau, 2011). Thus, to remain relevant over time, the components of the measure must accommodate change to the structures and processes necessary to achieve progress.

Other insights from the literature on health system integration evaluation which are relevant to this study include that:

1. Definitional ambiguity previously noted translates into fuzzy borders between organizational and regional or geographical integration of services. Both can be legitimate measures of system performance but the connections must be explicit (Provan & Milward, 2001);

2. Traditional evaluation methods such as randomized controlled trials, may not be appropriate as they are less able to account for the multi-disciplinary and multi-level milieu and dynamic nature of integration processes (Shaw et al., 2011);

3. Measures may examine the structures (precursors), processes (or intermediate outcomes) or outcomes of integration as suggested by (Donabedian, 1988), but are optimal when matched with conceptual frameworks and definitions (Strandberg-Larsen & Krasnik, 2009);

4. Evaluation studies of integration needed to be informed by appropriate theory and include both qualitative and quantitative methods (Shaw et al., 2011; Strandberg-Larsen & Krasnik, 2009);

5. A wide variety of methods are used for data collection however questionnaire surveys and self-report tools are the most prevalent in integration research. Few allow for the calculation of means or ranks, and few investigate inter-sectoral integration (Ahgren & Axelsson, 2005; Shaw et al., 2011; Strandberg-Larsen & Krasnik, 2009);

6. When devising a methodology for evaluation of system integration, what is to be measured must clearly derive from the goals of the system, the goals and enablers of the integrating mechanisms, and the context of the environment. Early research indicates that specific tools which are simple and suitable for use in the field would be beneficial, as would novel measures (Strandberg-Larsen & Krasnik, 2009); and finally, that

7. Further research is required to develop standardised and validated tools and indicators to measure integration across different settings (Shaw et al., 2011).

Despite the barriers to measurement and nascent stage of the integration performance measurement domain, there are numerous research studies which have developed indicators to measure the impact of integration on individual health systems.

2.2.4 Indicators of Healthcare System Integration

Methods to measure system integration vary considerably and the results have been mixed (Raina et al., 2006), with general agreement there are currently no universally accepted measures of integration

(Lloyd & Wait, 2006). Ling, Bardsley, Adams, Lewis, & Rolan (2010) proposed a research protocol for a portfolio of evaluation methods, both quantitative and qualitative, to measure the impact of integrated care projects in the United Kindgom. Their review of the literature suggests that integration initiatives improve care but are mixed in their impact on costs. Consistent with other researchers they caution that integration results are highly contextual, (Kodner & Spreeuwenberg, 2002; Minkman, Ahaus, & Huijsman, 2009; Shaw et al., 2011).

Some early studies suggest that certain outcomes should result from integration such as "growth of primary care and multi-specialty practices", "downsizing of acute care capacity" and "consolidation of programs and services" (Shortell et al., 1994), however the relevance of those indicators is heavily influenced by aforementioned context of the health system on which they were modeled. Wan, Ma, & Lin (2001) examined 100 integrated health networks (IHN) in the United States which were administratively and financially integrated. Using structure equation modeling, information integration (a scale variable indicating absence or presence of "integrated information systems") was not found to be associated with efficiency, and integration efforts did not impact profits or efficiency. However, the dependent variable in this study (presence on a list of "top 100 IHNs" determined by hospital utilization, contractual capabilities, service and access, physicians, financial positions, and system-wide integration) was created by a marketing group with no explanation of the algorithm by which IHNs were evaluated.

Browne et al. (2004), using a previously developed ordinal scale measuring integration depth, proposed the Human Service Integration Measure. This indicator is derived from information such as the number of services in the partnership, the "scope" as measured by awareness of or links between those services, and "depth" of the integration. The depth is measured by a 5 point Likert scale of non-awareness, awareness, communication, coordination and collaboration. Three years later Browne, Kingston, Grdisa, & Markle-Reid (2007) amended the model to include a measurement of the actual or observed assessment of the expected structural elements such as scope, depth and extent of network integration, the functioning of the network, and its outputs. This model appears loosely based on Donabedian's structure-process-output model of healthcare quality measurement. Consistent with this approach, integration measures are grouped by three dimensions:

1. Precursors of integration;
2. Intermediate outcomes or internal process variables; and
3. Outcomes measures that determine the extent to which systems are fulfilling their purpose.

Other studies use the BSC tool when measuring system integration and its impact (Armitage et al., 2009). As mentioned in Section 2.1.1. the BSC is used to capture a panoramic view of an organization or system, and to develop insight into its progress towards strategic goals by analyzing four perspectives: financial performance, customers, internal processes, and learning and growth. These perspectives may be adjusted when transitioning the tool to the non-profit sector or other novel setting but the essential mapping of each perspective to strategic goals does not (Kaplan, 2001). Balance is achieved through the selection and surveillance of leading (performance drivers) and lagging (performance outcomes) indicators, and between financial and non-financial indicators. This notion allows for "feedforward" and "feedback" controls, and to balance retrospective "corrective actions" with prospective "improvement actions" (Holmberg, 2000), a concept which is crucial to timely evaluation of complex interventions such as electronic health information exchange.

Identifying leading performance indicators in a system is inherently more difficult as it is predicated on a proven correlation between the indicator and the outcome of interest over time. So, for instance, a retroactive measure of quality emergency room care might be the time it takes for a patient to be admitted if required. A leading indicator of that quality might be the number of patients in the hospital who are designated as requiring an alternate level of care. Were they moved to that care setting they would free a bed and reduce the time it takes for an emergency patient to be admitted. The former measure informs the hospital they have a problem, the latter indicator gives them information to prevent it. The more time between indicator and effect, the larger the window of opportunity to implement corrective action. Leading indicator's capacity to anticipate outcomes and provide real-time feedback makes it particularly powerful in large, complex systems such as healthcare.

Canada's provincial departments of health are responsible for the delivery of healthcare services to their constitutents and therefore monitor macro-level or system-level performance measures including, though not consistently, system integration (Green & Moehr, 2000). The Strategy and Alignment Branch of Ontario's Ministry of Health and Long Term Care (2011) has developed a BSC- inspired mapping of performance indicators to government healthcare system priorities. Amongst outcomes such as effectiveness, safety, equity and a focus on population health, integration is presented as contributing to healthier communities by improving access to care. The three proxy indicators of system-level integration in that matrix are "percentage ALC (Alternative Level of Care) days", "ALC Days", and "Hospitalization Rate for Ambulatory Care Sensitive Conditions (ACSC) " measured using aggregated hospital sector data.

There is anecdotal evidence of a lack of integration co-existing with high ALC rates in the Ontario healthcare system (The Change Foundation, 2010b). Unlike many system indicators an Ontario benchmark for the percentage ALC bed days indicator is listed at the time of writing, as 8.5% for large teaching hospitals, 5.5% for community hospitals, 9% for complex continuing care and rehabilitation hospitals and 0.3% for specialty hospitals, with a “theoretical best” of zero (Ministry of Health and Long Term Care, 2012) . It is not without irony that this “system” integration measure is currently used to hold Ontario’s acute care hospitals to account for what is deemed to be inefficient institutional service delivery. Yet nominally and by its very nature, a high ALC rate is more reflective of downstream inefficiency and lack of capacity in regional health systems in Ontario. Nevertheless, this indicator is perhaps the only widely reported system integration measure in the Ontario system, and thus may be useful for validation of this study’s final integration indicator.

The selection of these system integration measures is generally affected by the need for parsimony in performance monitoring measures, attribution to a hypothesized chain of events in a causal pathway, and availability of data. However, there are few tools available to calibrate the correlation of the indicator with the phenomenon. Furthermore, those measures which are used, such as ALC and ACSC (above), have an almost exclusively retrospective performance lens providing little opportunity for governors and managers to adjust resources and priorities in real-time. It would appear that, in the context of Ontario’s healthcare system at least, there is a clear need for further research into measures of healthcare system integration which not only drive accountability but are sufficiently timely to influence future priority-setting.

As previously noted, the literature has alluded to the need for robust information systems to facilitate information exchange in integrated systems. Interoperability is the concept we use to understand how systems communicate with each other (Gibbons et al., 2007); it also facilitates the electronic exchange of information of interest to this study. Interestingly, integration and interoperability in the business literature are often used interchangeably and refer to the “ability of diverse organizations and their underlying information systems to work together (or interoperate) seamlessly" (Mouzakitis, Sourouni, & Askounis, 2009, p. 128). It is to this concept that we now turn to gain a theoretical understanding in order for it to be incorporated into our explanatory model.

2.3 Inter-Organizational Electronic Data Exchange and Interoperability

Electronic information exchange between two or more organizations cannot occur without some form of interoperability between their respective information systems (Carney, Fisher, Morris, & Place, 2005). In the context of this research study interoperability refers to electronic interoperability, defined by the Institute of Electronic and Electrical Engineers as:

> "The ability of two or more systems or components to exchange information and to use the information that has been exchanged." (Institute of Electronical and Electronics Engineers, 1990, p.42)

Gibbons et al. (2007) point out that this is just one of many documented definitions and that it falls short of describing the different types of interoperability which are key to scoping, planning and measuring interoperability levels. However, the definition is enduring in part because of its generality and ability to simply describe a concept which is complex in execution. Here interoperability will be presented as one functional component of healthcare systems integration; that is interoperability is necessary but not sufficient for a state of full integration amongst a network of health entities. As previously noted, in the business literature "integration" is a term commonly referred to as the outcome of two or more businesses' information systems sharing commonly understood data. Interoperability is the potentiality for that integration (Mouzakitis et al., 2009) that in its most rudimentary form results in electronic information exchange. It is rare that a network or system of organizations would plan for and implement a common set of electronic applications, reference models and shared vocabularies; therefore most networks of organizations develop interoperability post facto, with the goal of resolving the “multiplicity and heterogeneity” of the underlying sources of data and legacy applications (Manso & Wachowicz, 2009, p.1). Furthermore, application developers can be expected to make decisions about data format and structure in such a manner as to optimize their own system and in doing so will tend to make the process of connectivity with other systems more complicated.

Typically there are multiple information systems within an organization providing users with the information they need to make decisions. It is common for these systems to be isolated from each other, and also from the information systems of key stakeholders externally. The importance of shared information and information flows between entities in successful supply chain networks is well established in contemporary business literature (Giachetti, 2004). Disconnection comes at a price; in the US automotive sector alone, the inability to seamlessly share information across the supply chain is estimated to cost the industry about $1 billion annually (Brunnereier & Martin, 2002). When automation of joint activities occurs through “b2b interoperability” enterprises see improved quality from reduced process times, errors and costs (Mouzakitis et al., 2009). The magnitude of estimated savings from interoperability in healthcare is commensurate with the size of that sector. Pan and colleagures (2004) calculation of interoperability benefits to the U.S. healthcare system suggests that the cumulative benefit over the first ten years from fully interoperable electronic systems is $337 billion and $77.8 billion annually thereafter.

As the need for organizations to dynamically interact with other enterprises has grown, there has been increasing interest in building physical components, applications and business processes which are coordinated both internally and, as appropriate, with external partners (Chen, Doumeingts,

& Vernadat, 2008). Where electronic information is shared inter-organizationally the integration between systems has been mostly facilitated amongst larger organizations through electronic data interchange (EDI) (Stefansson, 2002). Small and medium sized organizations continue to rely on fax and telephone for information exchange, however the internet is offering solutions which make ubiquitous, secure, affordable electronic information exchange accessible even for the smallest business entities (Stefansson, 2002).

Before data exchange can take place, whether directly or indirectly through an intermediary such as a centralized data repository or by human intervention, organizations within a network or system must find a level of technical, syntactic, semantic and process interoperability which is acceptable to both the sender and receiver of information. Technical interoperability refers to the presence of some type of physical infrastructure and communication protocols to exchange data (referred to as Infostructure by Canada Health Infoway, 2006). Syntactic interoperability refers to data which is unambiguously defined by a common structure and format that is capable of being exchanged. In some cases, standards for interoperation between software applications i.e. syntactic interoperability, is subsumed under technical interoperability (Chituc, Azevedo, & Toscano, 2009), in others syntactic features of electronic information exchange are included under semantic.

In unbounded systems such as those imagined for health information exchange between a multiplicity of heterogeneous providers, the systems may need to interact effectively in the absence of complete and correct information, which is why semantic interoperability is so important in the healthcare domain (Carney, Smith, & Place, 2005). Semantic interoperability refers to the ability of receiving organizations to unambiguously interpret exchanged information in exactly the same way as the sending organization. So, for instance, one system's "Gender (M/F)" would be the corresponding system's "Sex (M/F)", or would ensure that "sodium pentothal" in one system is mapped to “pentothal” in another, and this would be understood by both. Naturally, without technical and syntactic interoperability semantic interoperability is impossible suggesting that there is some hierarchy to this concept (Panetto, 2007). Generally, developing semantic interoperability involves the use of such tools as ontologies and specialized vocabularies (Chituc et al., 2009; Mouzakitis et al., 2009). Ontologies are a specification of reality; they describe the concepts associated with a domain or artifact, and through a systematic description highlight the interrelationships and constraints between the concepts. Due to their ability to check logical ambiguity and detect inconsistency they are playing a central role in the development of standards to support semantic interoperability in many domains including healthcare (Kuziemsky & Lau, 2010; Raghupathi & Umar, 2011).

Process or enterprise interoperability assumes technical, syntactic and semantic issues have been resolved and focuses on the ability of entities to collaborate beyond organizational boundaries. It includes issues such as document management, governance of shared information, policies related to vocabulary and standards updates, goals, and common workflows.

The complexity inherent in industry or domain-wide solutions to systems interoperability requires the use of organizing frameworks. These systems’ interoperability frameworks have been well documented in military, engineering, government, and business literature over the past thirty years. The earliest were developed by the military in response to their inability to effectively communicate during joint and multi-national operations (Ford, Colombi, Graham, & Jacques, 2007; LaVean, 1980). Their desire to rank and measure progress towards systems’ interoperability resulted in frameworks that focus on layers or levels which establish a hierarchy and denote the maturity of the enterprise systems i.e. their potential for interoperability (Clark & Jones, 1999; Kasunic, 2003; LaVean, 1980; Searle & Brennan, 2005; Tolk & Muguira, 2003). Table 1. provides an overview of key interoperability frameworks from the military, business and health literature to date.

It is clear that there is no consistent application of terminology or agreement on definitions or categories across the various models and literature, although we note that underlying concepts are generally hierarchical and broadly comparable. While framework terminology is heterogeneous, a generic interoperability framework should account for technical, syntactic, semantic, organizational and network constructs; each successive level of interoperability being more or less dependent upon a demonstrated degree of capability in the preceding level. For example syntactic interoperability is not possible without some level of technical interoperability, semantic without syntactic and so on. The context in which a framework is developed determines whether its primary focus is technical (focused on the exchange, format and use of data), such as the NC3TA, LCIM, and the Levels of Health Information Exchange and Interoperability, or whether the framework's scope extends into interoperability at an organization or enterprise level, where shared value systems, goals and workflows are also considered such as the Business Interoperability Framework, C^4IF, or LISI.

The more expansive models, which include an organizational or enterprise level, support the findings from organizational information processing theory, that improving processes which increase information flows will reduce uncertainty within an organization (Premkumar, Ramamurthy, & Stoak Saunders, 2005); however they assume a level of sophistication and capacity in the preceding levels. Some of the models included in the table are intended as conceptual frameworks (Gibbons et al., 2007) to clarify terminology, while others have been designed with specificity and accompanying metrics to function as performance measurement or assessment tools (Kasunic, 2003; Pan, Johnston, Walker, Adler-Milstein, & Middleton, 2004).

Table 1. Overview of Key Interoperability Frameworks/Models

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
1980	(LaVean, 1980)	Defense Information Systems Agency (DISA)	Spectrum of Interoperability Model (SoIM)	Technical/ Organization	Level 1 – Separate systems Level 2 – Shared resources Level 3 – Gateways Level 4 – Multiple entry points Level 5 – Conformable/compatible systems Level 6 – Completely interoperable systems Level 7 – Same system
1989	(Mensh, Kite, & Darby, 1989)	MITRE	Quantification of Interoperability (QoIM)	Technical/ Organization	Seven components: 1. Media 2. Languages 3. Standards 4. Requirements 5. Environment 6. Procedures 7. Human factors
1993	(Kasunic, 2003)	MITRE (C4ISR Integration Task Force)	Levels of Information Systems Interoperability (LISI)	Technical	Level 0 – Isolated: manual extraction and integration of data Level 1 – Connected: peer-to-peer simple data exchange i.e. voice, text, email Level 2 – Functional: system to system using simple formats Level 3 – Domain: system to system database connections with common business rules Level 4 – Enterprise: enterprise-wide shared applications with common interpretation of

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
					data Within each level four attributes determine capacity for interoperability: procedures, applications, infrastructure, data (PAID)
1999	(Clark & Jones, 1995)	Australian Department of Defense	Organizational Interoperability Maturity Model (OIM)	Organization	Level 0 – Independent: no common goals or planned interaction Level 1 – Ad hoc: some overarching shared goal and some guidelines for interaction Level 2 – Collaborative: organizations still distinct, shared goals & roles, frameworks in place to support interaction Level 3 – Integrated: share goals, frameworks in place but still have responsibility to home organization Level 4 - Unified: unified organization where goals are shared and there is full interoperation
1999	(Searle & Brennan, 2007)	North American Treaty Organization (NATO)	NATO C3 Technical Architecture Reference Model for Interoperability (N3CTA)	Technical	Degree 1 – Unstructured data exchange: human interpretable, unstructured Degree 2 – Structured data exchange: automated but requires manual intervention Degree 3 – Seamless sharing of data: common model Degree 4 – Seamless sharing of information: universal interpretation

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
2003	(Tolk & Muguira, 244 003)		Levels of Conceptual Interoperability Model (LCIM)	Technical	Level 0 – System specific data: no interoperability Level 1 – Documented data: shared protocols Level 2 – Aligned static data: common reference model & ontology Level 3 – Aligned dynamic data: data defined by common engineering languages Level 4 – Harmonized data: explicit & transparent semantic interoperability
2003	(Tolk, 2003)		Layers of Coalition Interoperability (LCI)	Technical/ Organization	Layer 1 – Physical interoperability Layer 2 – Protocol interoperability Layer 3 – Data/object model interoperability Layer 4 – Information interoperability Layer 5 – Knowledge/awareness Layer 6 – Aligned procedures Layer 7 – Aligned operations Layer 8 – Harmonized strategy/doctrines Layer 9 – Political objectives
2003	(Government of Austraila, 2006)	Australian Government	Australian Government Technical Interoperability Framework	Technical	Three “interoperability aspects”: Technical Information Organization
2004	(Morris, Levine, Meyers, Place, & Plakosh, 2004)	Carnegie Mellon for the U.S. DoD	System of Systems Interoperability (SOSI)	System	Program Management: activities to manage acquisition – focus on contracts, incentives etc. System Construction: activities to create and system a system –

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
					focus on architecture, standards etc. Operational System : activities to operate a system – focus on interactions with other systems
2004	(European eGovernment Services, 2004)	Council on Interoperable Delivery of pan-European Services to Public Administrations Businesses and Citizens (IDABC)	European Interoperability Framework (EIF)	Technical/ Organization	Three dimensions of interoperability: Dimension 1. Technical Dimension 2. Semantic Dimension 3. Organizational
2004	(Pan, Johnston, Walker, Adler-Milstein, & Middleton, 2004;Walker et al., 2005)	Center for Information Technology Leadership (CITL)	Levels of Health Information Exchange and Interoperability (HIEI)	Technical	Level 1 – Non-electronic data transfer i.e. mail, phone Level 2 – Machine-transportable data transfer i.e. fax, email, pdf. Requires human intervention Level 3 – Machine-organizable data transfer i.e. HL7 messages. No human involvement in data exchange but no uniform standards Level 4 – Machine-interpretable data transfer i.e. automated entry of LOINC results from lab to EMR. Full syntactic & semantic interoperability
2005	(ATHENA European Integrated Project, 2006)	Advanced Technologies for Interoperability of Heterogeneous	Enterprise Interoperability Maturity Model (EIMM)	Technical/ Organization	Six areas of concern: 1. Business strategy and processes 2. Organization and competences

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
		Enterprise Networks & their Applications (ATHENA)			3. Products and services 4. Systems and technology 5. Legal environment, security and trust 6. Enterprise modeling Five levels of maturity: 1. Performed – ad hoc 2. Modeled – meta models applied, network technologies 3. Integrated – documented enterprise modeling internally 4. Interoperable – enterprise models adapt to changes of external entities 5. Optimizing – enterprise models react and adapt to changes in business environment for improvement
2005	(NEHTA, 2005)	National E-Health Transition Authority	E-Health Interoperability Framework	Technical/ Organization	Technical – standards, certification and connectivity architecture Information – information “building blocks” such as data formats and terminologies Organizational – enterprise processes such governance, finance and policies
2006	(Peristeras & Tarabanis, 2006)		Connection, Communication, Consolidation and Collaboration Interoperability	Technical/ Organization	Connection (Channel layer/Signal): exchange information signals Communication (Information layer/Syntactic): exchange data in predefined data format and

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
			Framework (C^{4}IF)		schema Consolidation (Information layer/Semantic): able to understand exchanged data i.e. reference ontology Collaboration (Process layer/Action-Behavioural): understanding of functions/services/processes arising from data exchange
2006	(Daclin, Chen, & Vallespir, 2008)		Enterprise Interoperability Measurement	Technical/Organization	3 Types of Compatibility: Conceptual: Syntactic, semantic Technological: Platform, communications Organizations: Persons, organization
2006	(Legner & Wende, 2006)		Business Interoperability Framework	Organization	Management of external relationships Collaborative business processes Employees and culture Information systems
2007	(Gibbons et al., 2007)	HL7	Hierarchy of Interoperability	Technical/ Organization	Technical: conveyance of data Semantic: mutual understanding of shared data Process/social: integration of shared data into workflows
2009	(ISO/European Committee for Standardization (CEN), 2009)	ISO	Framework for Enterprise Interoperability (FEI)	Organization	Data – ability of entities to exchange data, both electronic and non-electronic Services – the ability to request, provide and utilize each other's services Process - ability to link to perform collaborative processes

Date	Source [Citation/s]	Institution	Name	Primary Focus	System Levels/Categories
					Business – level of compatibility in goals, decision-marking, culture, regulatory constraints etc.
2011	(Guédria, Bouzid, Bosh, Naudet, & Chen, 2012; Guédria, Naudet, & Chen, 2011a)		Maturity Model for Enterprise Interoperability (MMEI)	Organization	Level 0 – Unprepared : no capability for interoperation Level 1 – Defined: capable of modeling & describing systems Level 2 – Aligned: capable of aligning to common standards & formats Level 3 – Organized: capable of meta modeling to tamp amongst heterogeneous partners Level 4 – Adaptive: capable of negotiating and dynamically accommodating heterogeneous partner Within each level conceptual, technological and organizational interoperability is evaluated against four “enterprise concerns”: data, service, process & business.

Transmitted information’s syntactic and semantic qualities will determine the level of automation possible when exchanging data between electronic systems (Klischewski, 2004). When the focus is on establishing automated information flow, the levels of system interoperability range from having no interoperability, that is systems are isolated and exchange of data or information is non-electronic and requires human intervention for transmission and interpretation, through to semantic interoperability, where shared data is exchanged electronically in standardized format, both sender and receiver mutually agree on the meaning of the content, and electronic exchanges are transacted to completion without human intervention. Health information systems which are fully interoperable and where electronic information flows freely, are intended to disguise the previously mentioned “multiplicity and heterogeneity” of the underlying sources of data (Manso & Wachowicz, 2009), facilitating what has been described as “seamlessly integrated clinical information” (Bisbal & Berry, 2011, p. 181).

LaVean's (1980) groundbreaking work on military interoperability suggested that both technical and non-technical or organizational components were required. However it wasn’t until much later in the context of joint military operations, that this concept reappeared through Clark & Jones' (1995) Organizational Interoperability Model (OIM), and interoperability at an organizational level (including operations, process and culture) was paired with that of systems at the technical level. The OIM framework refers to five levels of organizational interoperability which mimic health system integration frameworks. In fact, the OIM Level 3 category is nominally referred to as “integrated”, and its description of shared values, goals, and processes amongst organizations which retain their autonomy, closely resembles postulated ideal models for integration in a successful healthcare system.

While the enterprise architecture (the structure and processes as well as the infostructure) of a system is key to understanding its behaviour (Chen et al., 2008), resource constraints and the embryonic stage of networks of interoperability in Ontario's healthcare sector, warranted a focus on examining interoperability levels and electronic information exchange at the foundational or technical levels. However, our understanding of interoperability would be incomplete without acknowledging the presence and importance of its spectrum of levels.

Of particular relevancet to this project is the work by Clark & Jones (1999) who hypothesized that the OIM categories for organizational interoperability can be mapped to the LISI levels of technical interoperability. Extrapolated further, Table 2 demonstrates the conceptual alignment between technical interoperability and organizational interoperability, and the healthcare Continuum of Integration model previously introduced in Figure 2. The theoretical linkage strongly supports an hypothesis of a relationship between electronic health information exchange and system level integration.

Table 2.Alignment between Interoperability Models and the Continuum of Integration

Technical		**Organizational**		**System**
Levels of Information System Interoperability (LISI)		Organizational Interoperability Maturity Model (OIM)		Continuum of Integration
Isolated	→	Independent	→	Full segregation
Connected	→	Ad hoc	→	Coordination
Functional	→	Collaborative	→	Collaboration
Domain	→	Combined	→	Linkage
Enterprise	→	Unified	→	Full integration

For the purposes of this research study, an appropriate framework will contribute to the development of a conceptual model of regional clinical information flows which arise as a result of information system interoperability within an integrated health system. This framework will contribute to the development of a data collection tool to support our research assertions. In the following section, a review of the current state of healthcare interoperability will be used to guide the development of the final framework, and is included here to support the need to focus on lower levels of technical interoperability for current system-level electronic health information exchange measurement.

2.3.1 Healthcare Interoperability and Information Exchange

Interoperable electronic health information systems provide a means for the exchange of clinically relevant patient/client data; as such information exchange, facilitated by interoperability, is a process which contributes to the goal of ensuring all relevant information is available for decision-making by healthcare providers. In a healthcare system such as Canada's, consumers are able to determine from whom and where they seek medical care; as a result there is a high likelihood of having clinical information spread across a wide array of locations, autonomous systems and providers, many of whom may be unaware of the others' presence. In the U.S. the situation is not all that different; one study on Medicare beneficiaries (those over 65 or with chronic illness) found patient/clients with over six unique physicians during 15 visits each year. Those with serious chronic diseases had almost 38 visits and saw 13 unique physicians in a year (Berenson & Horvath, 2002, p.9).

When one additional provider is added to a care team, the scope of the communications required to convey information to each member is combinatorial; that is the total number of exchanges to ensure everyone is informed is denoted by $n!/(r!(n-r)!$, where n is the number of providers and r is the number of individuals involved in the exchange (Coiera, 2006). Each physician visit may initiate referrals or exchanges with numerous other healthcare services such as pharmacies, laboratories, hospitals, specialists, and imaging facilities; these in turn generate new information to be shared amongst health service providers who are increasingly urged to base clinical decision-making on evidence (Dykes & Bakken, 2004). The opportunities for exchange are myriad, as is the likelihood of information going missing (Bodenheimer, 2008). Paper-based clinical information systems are practically limited in their ability to efficiently manage and support growing expectations of quality, evidence-based practice and team-based care (Rodrigues, 2000; Hersh, 2002; Young, 2007), thus providers are increasingly turning to electronic information systems to assist with the gathering and management of patient/client clinical data (Schoen & Osborn, 2009; Schoen et al., 2009).

The goal of healthcare information systems use is to achieve what Uschold & Grenier (2004) refer to as the "holy grail…of fully automatic semantic interoperability among independently developed and heterogeneous agents". In this scenario, relevant clinical information about the right patient/client is available to healthcare providers in the time and place where its use can effect the greatest impact on quality of care provided to that individual. In the aggregate the same would be possible for larger populations as information is shared and aggregated nationally and internationally, and policy and strategy is derived from meaningful inductions from real-time data. Implicit in this scenario are the assumptions of a commitment between all providers to a shared understanding of all exchanged data, sufficient trust to both send and receive information securely, and to ensure its appropriate use by authorized personnel; all necessary conditions on the road to fully interoperable clinical information exchange.

However, we are far from this utopian state. In 2010 only 37% of Canadian doctors reported use of an electronic medical record (the necessary foundation for clinical interoperability), averaging from 62% in Alberta to 22% in Quebec despite evidence of overwhelming support of their belief in the benefits of information sharing (Canada Health Infoway, 2010). By 2012 the number of family physicians was recorded at 56% (Canada Health Infoway, 2012); no figures are available on other physician or healthcare sectors.

A 2008 PricewaterhouseCoopers' survey of international health executives and thought leaders ranked "better coordination of care" and "improved and faster information sharing" as the two most likely actions to "greatly improve quality" (PricewaterhouseCoopers' Health Research Institute, 2008, p. 24). While evidence to support that opinion is not categorical (Lau et al., 2010), the prevailing opinion is that when organizations collaborate, they will be more effective (Provan & Milward, 2001). This is born out internationally by health information exchange policies and projects such as in the United States with the advent of the Health Information Technology for Economic and Clinical Health (HITECH) Act, the National Health Information Infrastructure (NHII) and a growing number of regional health information organizations which will eventually contribute to a National Health Information Network (NHIN); Canada's establishment of Canada Health Infoway to develop a pan-national electronic health record; Australia's National E-Health Transition Authority (NEHTA) (Sprivulis et al., 2007); and the United Kingdom's NHS Connecting for Health initiative (Bisbal & Berry, 2011).

In Canada substantial federal, provincial and private financial resources have been invested in health enterprise architecture and applications which could enable electronic collection, storage and sharing of healthcare information. Canada's vision of IT-enabled health information includes the creation of a secure pan-Canadian infrastructure that would freely transmit data between healthcare providers whenever and wherever citizen’s sought care (Canada Health Infoway, 2007). In their infrastructure blueprint Canada Health Infoway (2009) identified the need for “clinically relevant data” to be shared beyond organizational boundaries, for “accurate, complete, timely delivery of information shared across multiple organizations and jurisdictions”. Infoway has also noted that the complexity of the challenge to provide an “integrated view” of patients/clients arises from the large number of potential points of service, security, governance and access issues.

The challenge of integrating healthcare information in the face of a multitude of heterogeneous systems has not been lost of previous researchers and practitioners who compare the situation to a technical Tower of Babel (Grimes, 2006; Li, Zhou, Chu, Araki, & Yoshihara, 2011) requiring the adoption of industry-wide terminology and format standards. Others have suggested that patient/client privacy concerns (Edwards, Hollin, Barry, & Kachnowski, 2010; Webster, 2011b), the lack of common data reference models, standards and vocabularies or mappings between them (Channin, Parisot, Wanchoo, Leontiev, & Siegel, 2001; Coiera, Aarts, & Kulikowski, 2012; Scott & Worden, 2012) and the fact that funding for interoperability competes with other quality improvement efforts, many of which have a stronger business case for development (Brailer et al., 2003), are responsible for slow adoption.

Using the Levels of Health Information Exchange and Interoperability framework, Walker et al. (2005) calculated the savings of a fully networked, semantically interoperable clinical information exchange in the U.S.; this potential for productivity gains has driven interoperability implementation projects & research (Bouhaddou et al., 2008; Charalabidis, Penetto, Loukis, & Mertins, 2008). The large majority of peer-reviewed publications on health information exchange since 2000 originate from the U.S. and are related to Health Information Exchanges (HIEs) or Regional Health Information Organizations (RHIOs), and their efforts to quantify the business case for interoperability development (Adler-Milstein, Bates, & Jha, 2009). This literature warrants mention as it provides insight into the value of shared clinical information, the different types and sources of information which have proved to be useful for exchange, and models for the exchange infrastructure; whether it is a federated model with data distributed amongst independent provider registries with an access layer, a centralized structure with data warehousing, information distribution (one-to-many), or a one-to-one model such as EDI (Eckman, Bennett, Kaufman, & Tenner, 2007).

There has been renewed interest in health information exchange organizations in the United States., perhaps as a result of the American Recovery and Reinvestment Act of 2009 and its Meaningful Use criteria (Vest, Gamm, Ohsfeldt, Zhao, & Jasperson, 2011). However, the focus has shifted from the latest RHIOs to a more centralized web-based approach, and point-to-point exchange between providers as the country develops their Nationwide Health Information Network (NwHIN) (Lenert, Sundwall, & Lenert, 2012).

Adoption of standards is critical to stakeholders' trust in the quality of information exchanged and their ability to realize the value of their investments in electronic medical records and the sharing of information (Cao, Archer, & Poehlman, 2009; Edwards et al., 2010). A number of different initiatives promoting standardization and semantic interoperability are ongoing, such as the development of the Health Level 7 (HL7) reference information model and messaging (Landgrebe & Smith, 2011; Orgun & Vu, 2006), the International Health Terminology Standards Development Organization (IHTSDO) which maintains and develops the Systematized Nomenclature of Medicine – Clinical Terms (SNOMED) terminology, and Integrating the Healthcare Enterprise's (IHE) Cross-Enterprise Document Sharing (Bisbal & Berry, 2011; Channin et al., 2001). Many jurisdictions have previously avoided using draconian measures to promote adoption of common standards, preferring instead to underwrite activities such as those undertaken by these organization to promote their development and use (Webster, 2010).

Inevitably, the approach to interoperability and information exchange in healthcare will be highly contextual, and driven by the perceived value to those making the substantial investments required to convert paper to digital records, then align systems and data to facilitate information exchange with other healthcare providers. That paper-based health information is being systematically transformed to digital format is unquestioned; however the rate at which that digital information is shared is less understood and more complex to measure as we will discover in the following section.

2.3.2 Measuring Electronic Interoperability and Information Exchange

Kasunic & Anderson (2004, p16) have stated that “measuring, assessing, and reporting interoperability in a visible way is essential to setting the right priorities”, noting at the same time that “developing and applying precise measurements… is difficult.” Systems are defined by their inputs, processes and outputs. Outcomes measure the impact of outputs on the system. Outcome performance indicators are hard to devise and some believe challenging to measure in service industries (Whyte & Bytheway, 1995). Even when they are available, it is difficult to disentangle the causative factors. Typically long timelines may result in attribution bias with outcome measures (Donabedian, 1966; Freeman, 2002; Jolette & Manning, 2001) and they are also subject to many other serious and subtle biases (Davies & Lampel, 1998). For these reasons, many organizations revert to measuring combinations of process and output/outcome performance indicators (Adair et al., 2006; Baker & Pink, 1995; Beattie & Mackway-Jones, 2004).

Mant (2001) claims that there has been a strong case made for the exclusive use of process performance indicators in healthcare in recent years, particularly where a ‘relationship’ has been established between process and outcome. However, Donabedian (1966) cautions that multi-dimensional assessment of medical care is costly and laborious, and that simple indices should be found and justified through proof and appropriate correlative power.

Many of the frameworks presented in Table 1 were developed as measurement tools, and many document interoperability metrics which allow stakeholders to assess their current state and monitor progress through higher interoperability layers or maturity levels. The military in a number of countries focused their efforts on building the capacity of their forces to exchange information with each other as well as with multilateral forces thus required a method that could measure, report and improve interoperability capacity (Ford et al., 2007). The reasons for this early interest included the dynamism and diversity of operations, the increasingly collective approach to international engagement thus heterogeneity of information systems which need to interoperate, short lead times, and increasing expectations of public accountability for the effectiveness of military operations (Moon, Fewell, & Reynolds, 2008). In parallel, due in part to globalization, growing accessibility and productivity of technology, and the potentially grave consequences of information exchange deficiencies, there has been emergent interest in the classification and measurement of systems interoperability in the business and health domains. In healthcare, until more recently, the focus has been on the evaluation of individual applications or projects rather than on the impact of interoperability on the system as a whole. Before the assignment of value, however, we must categorize and measure the levels of interoperability - as a multi-dimensional construct it presents some interesting measurement challenges.

2.3.3 Electronic Health Information Exchange and Interoperability Indicators

Table 3 summarizes measures of system-level electronic information exchange and interoperability obtained from the peer-reviewed literature. Where available, methods used for data collection and analysis have been included to better understand the context of the measures. Most of the papers reviewed were theoretical rather than empirical. It is important to note that when measuring information exchange these studies also primarily focus on the lower interoperability levels (that is contributors to technical and syntactic interoperability).

Table 3. Electronic Information Exchange Indicators

	Citation	System Framework	Measure	Metrics related to information exchange usage	Domain/Approach /Data Collection Methods
1998	(Leite, 1998)	No	Interoperability Assessment	Describes a set of components of interoperability that can be measured: Common standards, requirements and data elements Connectivity index – measures ratio of available paths (connections) between the system nodes (participating units) Node connectivity – the % of messages sent which are received for each transmitting node Common protocols Information flow – volume of data: • Capacity – the rate of data flow over time • System overload – the number of messages remaining in queue after the transmission period • Underutilization – message load is less than capacity but queuing occurs • Undercapacity – message queuing occurs with maximum data rate Data latency – elapsed time from send to receive Interpretation – the receiving system responds	Military Subjective assessment & system log files

	Citation	**System Framework**	**Measure**	**Metrics related to information exchange usage**	**Domain/Approach /Data Collection Methods**
				correctly Information utilization – verification that the correct action is taken by the receiving system	
2004	(Liang, Xue, Byrd, & Rainer, 2004)	No	Inter-organizational document exchange	Volume – ratio of number of documents exchanged via EDI to total documents exchanged via all channels Diversity - number of different document types exchanged through EDI Breadth - the ratio of the number of external entities with which the hospital has EDI linkages to the number of all communicating external partners Depth – measured by "technical sophistication" denoted by data, data & text, and data, text & images	Business/Computing Self-reported survey
2005	(Sittig et al., 2005)	Donabedian's Structures, Process, Outcomes	Systems availability	# or % of patient/clients in a region with electronic data available # or % of clinicians with a system login # or % of entities in a region with a data exchange agreement	Healthcare Theoretical
			Systems use	# of patient/client's who's data was accessed by someone other than originator # clinicians who log into system # of entities submitting data to RHIO	
			Effect		
2006	(Labkoff & Yasnoff,	Yes	Functionality	Completeness of information (availability) – 0-5 scale for each of inpatient/client (hospital),	Healthcare

	Citation	System Framework	Measure	Metrics related to information exchange usage	Domain/Approach /Data Collection Methods
	2006)		of HIE	outpatient/client (ambulatory), long term care, home health/personal health record, laboratory results, outpatient/client medications, imaging and insurance claims Degree of usage – points added for % or patient/clients and providers using the system Type of usage – patient/client care, public health, clinical research, quality improvement & healthcare operations	Stakeholder interviews and researcher assessments
2006	(Daclin, Chen, & Vallespir, 2006)	Yes	Enterprise interoperability degree measurement	Time (duration) of exchange – ratio of expected minus actual duration of the exchange over the expected Quality of exchange – number of exchanges that succeeded over total number of exchanges Number of “conforming” exchanges over the total number received	Business Theoretical
2007	(T. Ford, Colombi, Graham, & Jacques, 2007)	No	i-Score	Quantifies the “spin” or interoperability between two systems or sets of systems which are performing “threads” or sets of activities. Optimal connectivity occurs when system pairs don’t require human or machine translation in order to interoperate i-Score is the product of all spins and threads in the system and is compared to the optimal i-Score (all possible spins and threads given the system constraints)	Military Theoretical

	Citation	System Framework	Measure	Metrics related to information exchange usage	Domain/Approach /Data Collection Methods
2007	(Cusack & Poon, 2007)	No	HIE	Volume - discrete clinical data elements moved Usage – number of data elements available versus those used Usage - ratio of patient/clients for which data available to those viewed by clinicians Timeliness – time from which data generated to when able to be viewed	Healthcare Theoretical
2008	(Adler-Milstein, McAfee, Bates, & Jha, 2008)	No	Clinical data exchange in a RHIO	Type of entity providing and/or receiving data – hospital, ambulatory MD/clinic, laboratory, imaging centre, payer (public and private), public health department, pharmacy, pharmacy benefit management organizations Types of clinical data exchanged – test results, inpatient/client data, medication history, outpatient/client data, public health reports	Self-reported survey
2011	(Vest, Zhao, Jaspserson, Gamm, & Ohsfeldt, 2011)	No	HIE usage	# and variety of HIE screens viewed per encounter	System log files
2011	(Vest, Gamm, et al., 2011)	No	Systems use	% of encounter-based usage of HIE % of retrospective usage of HIE	HIE logs examined for access per patient/client encounter

While we did not identify any publicly available, peer-reviewed and validated survey instruments measuring interoperability in healthcare, two Canadian examples of proprietary surveys were found which have been used to measure technology adoption, and in doing so touch on technical capacity for sharing electronic clinical information. These surveys, the Ontario Hospital Association (OHA) eHealth Adoption Survey and the Healthcare Information and Management Systems Society (HIMSS) EMRAM® survey will be reviewed given their potential for validating the results of an interoperability measure in Ontario.

The OHA eHealth Adoption Survey, was sponsored by the Ontario Hospital Association (OHA) and the Hospital e-Health Council, and funded by the Ministry of Health and Long Term Care. First administered in 2005, the survey was widely supported by OHA members with return rates over 90% (94% in 2007 and 97% in 2008) (McMurray, 2009). Results prior to 2007 were confidential; however from 2007 onwards, individual hospitals' aggregate results were made public allowing hospitals to rank themselves amongst their peers. The last survey results were published in 2008 (Ontario Hospital Assocation, 2008a). The methodology for data collection was similar to that used to administer the eHIE survey in this study. Responses were submitted by the hospital's chief information officer or their designate on behalf of the hospital corporation; data quality was validated using a cross-checking algorithm comparing responses to correlated questions within the survey. The instrument scoring methodology used an arithmetic mean of self-reported scale responses in several subsections:

1) electronic patient registration, records management, and registry services;
2) electronic order entry at point-of-care;
3) electronic clinical documentation;

4) electronic results reporting;

5) information infrastructure;

6) e-health leadership and planning;

7) inter-organizational data sharing; and

8) interoperability for a shared HER.

An audit of the survey methodology revealed no instances of intentional misrepresentation that might affect rankings (McMurray, 2009).

The last two sections of the Survey, 3.1 Inter-Organizational Data Sharing, and 3.2 Interoperability for a Shared EHR examined constructs of interest to this study. The sections required responses to questions from a Data Sharing Legend which assigned different scores to each response of: Identified, Acquired, In Progress, Pilot/Implemented, Mostly Implemented, and Fully Implemented.

Questions in 3.1 related to sharing of clinical document objects notably admission histories and physical exams, discharge summaries, patient referrals, drug profiles, lab results, diagnostic images, reports (imaging/surgical/procedural), and ER/ED visit encounter summaries. “Sharing” was defined as providing or receiving information electronically and were not scored independently, but the question referred to the functionality, or technical capability, to share the information not the flow of information itself.

Questions in 3.2 were less systematic in their approach, but used the Data Sharing Legend to rank responses to questions concerning functionality to support the hospitals’ ability to electronically interface with family health teams and send results to a shared repository. We hypothesized the

3.1constructs and scores for this section would be conceptually similar to those in our interoperability framework and eHIE scores for hospitals and could be used for comparison of hospital reported data.

HIMSS is a U.S. based non-profit organization which has developed the Electronic Medical Record Adoption Model or EMRAM®. This analytic framework allows hospitals to measure their progress towards digitization of medical records. However, as a propriety framework, a description of the data collection instrument and scoring algorithms is not available to those outside the HIMSS organization and there are no published studies of the development methodology, validity or reliability of results. Therefore EMRAM® results, while informative for comparison, must be viewed with some caution given the lack of transparency.

2.4 Summary of the Literature

Evaluation of a healthcare systems' performance is a critical component of accountability (Rigby, 2006). Yet we struggle to define, conceptualize and measure integration, a universal goal of major western healthcare delivery systems. While this is not unexpected in a dynamic and complex system such as healthcare, the lack of consensus on definitions and frameworks associated with integration creates problems in measurement and impedes our ability to identify and manage gaps and barriers which delay improvements to care quality and outcomes which result from integrated care. Consistent across the integration literature is that it results in "seamless" care, is rarely investigated at the system level or across sectors, involves a continuum from completely segregated to fully integrated, is highly contextual to the system it describes and would benefit from a clear theoretical model to support research into its measurement.

System-level interoperability measures, those which assess the performance of ultra-large scale socio-technical ecosystem such as healthcare and the military are clearly poorly represented in the literature. What is needed in healthcare is a simple indicator to measure interoperability; as Donabedian suggests, a ratio that allows the denominator (of maximum possible data that can be exchanged electronically) to change over time would be more appropriate and is more likely to ensure the sustainability and relevance of the metric. Furthermore, as clinicians are known to prefer to receive more clinical information than what they share (Rosenbaum et al., 2011), the direction and volume of information flows is also an important component of information exchange measurement; this component of information exchange is rarely examined. Despite considerable evidence supporting the value of summary indicators for system performance this is too is rarely reported in the interoperability measurement literature.

Interoperability is commonly linked to integrated care and healthcare system improvement. This relationship is rarely explicitly measured, nor empirically tested for effect, yet it is a “crucial indicator” of system performance according to Green & Moehr (2000, p319). The literature is clear that interoperability has an important role to play in ensuring that information is extracted from isolated systems and made available to inform clinical decision-making across the care continuum. This research study will demonstrate one method of quantifying electronic information flowing between healthcare providers in a healthcare network. It hypothesizes and pilot tests both an individual and system-level indicator of interoperability and examines the link between the electronic exchange of clinical information, and seamlessly integrated care within that system. Chapter 3 will describe the unifying framework that establishes the theoretic foundation for this relationship.

Chapter 3

Theoretic Framework

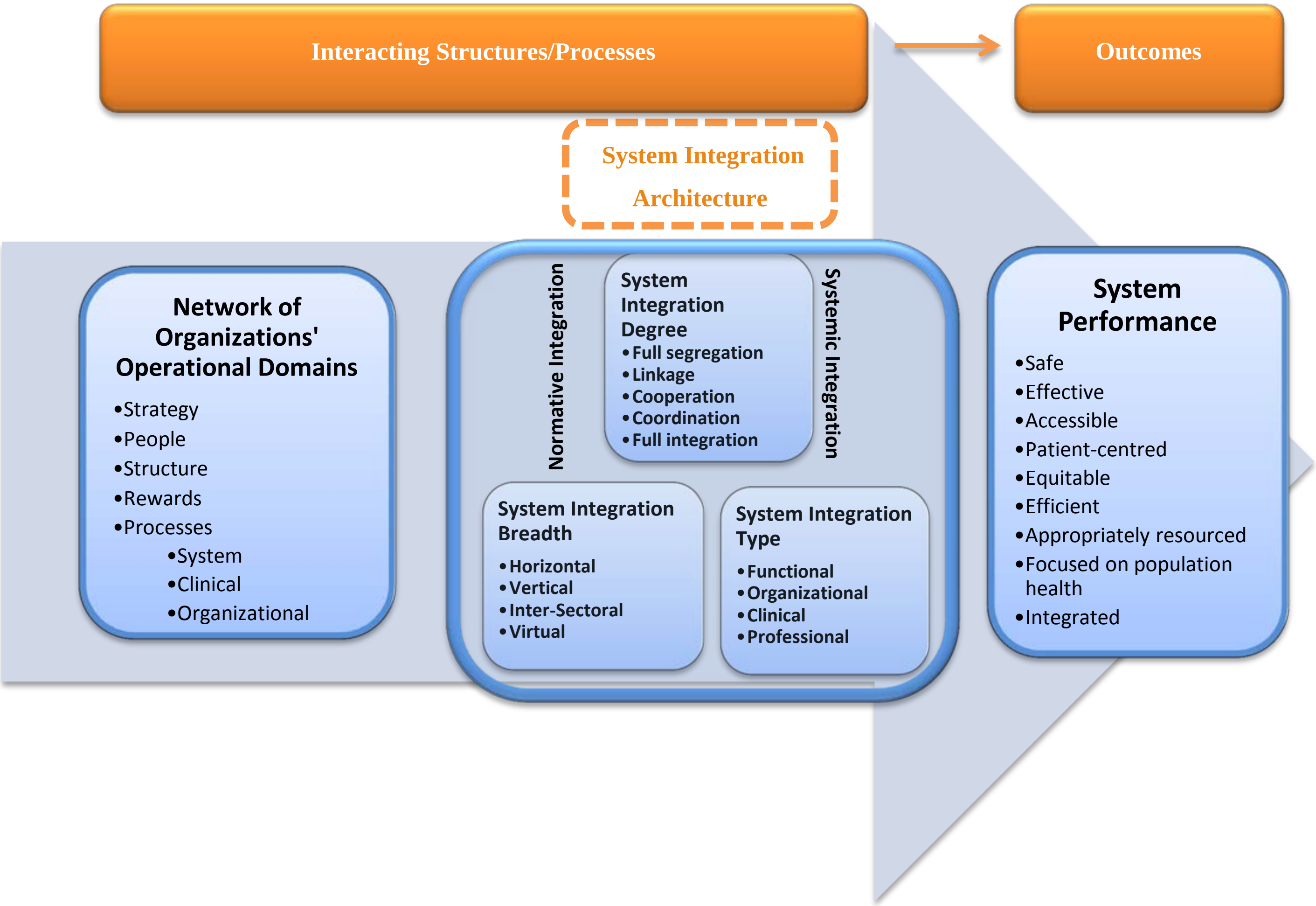
In order to measure electronic health information exchange and test our hypothesis of a relationship between interoperability and integration, the complexity and ambiguity of concepts in the current literature must be synthesized and presented in a simplified theoretical framework to guide the development and selection of appropriate measures.

3.1 Healthcare System Integration Framework

Emerging models of health systems as complex adaptive systems are currently being explored and examined (Begun, Zimmerman, & Dooley, 2003; Plsek & Greenhalgh, 2001), however Donabedian’s structures, processes and outcomes remain dominant for analysis and evaluation (Atun, 2012; Begun et al., 2003). Donabedian's (1988) model for quality measurement in health care identifies structures (such as the settings and instrumentalities of care delivery), and processes (such as the procedures and techniques of care delivery) that contribute to health care outcomes. Previous healthcare research has used the Donabedian model to classify policy and service interventions in a causal chain that suggests generic service interventions such as inter-organizational information exchange can be measured using changes in targeted or clinical processes (Lilford et al., 2010).

Others have modeled integration frameworks (Fulop et al., 2005; Gillies, Shortell, et al., 1993; Strandberg-Larsen & Krasnik, 2009), yet none has provided a comprehensive schema relating integration outcomes to measured inputs/processes. Figure 4 diagrams an archetype showing the interplay of components which theoretically contribute to outcomes in a successfully integrated healthcare system. An explication of the components now follows. In this archetype, the performance outcomes are drawn from the Ontario Health Quality Council's "attributes of a high performing healthcare system" (Ontario Health Quality Council, 2010, p.5).

Figure 4. Archetype of Successful Healthcare System Integration Measurement



A model of organizational structures and processes that contribute to integrated care is listed under “Network of Organizations’ Operational Domains” after Galbraith's (2002) Star Model. One small modification has been made to the Star Model’s domains; processes are broken out as system, clinical or organizational according to Macadam's (2008, p.3) “levels of integrative activities”.

The Star model of organizational design originates in the business literature where increasingly competitive and complex markets drive organizations to develop higher value, customized or customer-centric offerings using what is referred to as customer “solution selling”. This philosophy of organizational system-building to develop and deliver services in partnership with and valued by the end user is entirely consistent with contemporary beliefs in the benefits of patient-centred over provider-centred health care. The value of patient-centric care within health service organizations and its role in improving outcomes underpins the current drive toward seamlessly integrated care. The Star Model suggests that each organization’s “customer-centric solutions” involve the coordination and linking of a number of components i.e. strategy, people, structures, rewards and process. The Star Model has relevance to integrated healthcare systems which at their zenith should coordinate and deliver seamless care; that is a network of organizations which act in unison towards common goals, where patient-centric care delivers customer-centric “solutions” such as seamlessly integrated care. However, the more units coordinating to deliver customer-centric solutions, the greater the number of interfaces between providers and the greater the need for information and coordinating processes such as health information exchange (as previously noted Section 2.3.1, p.51).

Further theoretical support for the appropriateness of this approach is provided by correlating Suter et al.'s (2009) previously mentioned principles of integration, into the Star Model’s five operational domain categories with particular emphasis on its application at the system level. Table 4 demonstrates how integrated healthcare systems might operationalize a patient-centric solution using the components outlined in each of the “ten principles of integration” (Suter et al., 2009).

Table 4. Integration Structures and Processes by Operational Domain

Operational Domains (Galbraith, 2002)	Principles for Integration (Suter et al., 2009)	
	Integration Dimensions	Category[3]
Strategy	• Focus on wellness, health promotion & primary care	1
	• Patient-centred philosophy, focussing on patients needs	2
	• Organizational support with strong demonstration of commitment	7
People	• Leaders with vision able to instill strong, cohesive culture	7
	• Physicians are gateway to integrated healthcare system	8
	• Physician support for EMR	8
	• Physicians engaged in leadership role	8
Structure	• State of the art information systems to collect, track & report activities	6
	• Strong, focused, diverse governance with representation for all stakeholders	9
	• Organizational structure promotes coordination across settings & levels of care	9
Rewards	• Align service funding to ensure equitable funding distribution for different services or levels of services	10
	• Funding mechanisms promote inter-professional teamwork & health promotion	10
	• Sufficient funding to ensure adequate resources for sustainable change	10
Processes: System	• Multiple access points	1
	• Roster: resonsibility for identified poulation; right of patient to choose & exit	3
	• Population –based needs assessment, focus on defined population	2
Clinical	• Patient engagement & participation	2
	• Interprofessional teams across the care continuum	4
	• Diagnostis, treatment & care interventions linked to clinical outcomes	5
	• Evidence-based care guidelines & protocols toendorace one standard of care, regardless of where the patient is treated	4
Organizational	• Cooperation across the continuum	1
	• Maximize patient accessibility & minimize duplication of services	3
	• Commited to quality of services, evaluation & continuous care improvement	5

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[3] Legend for Table 4. Suter's Principles by "Category"

1. Comprehensive services across the care continuum
2. Geographic coverage and rostering
3. Patient focus
4. Standardized care delivery through interprofessional teams
5. Performance management
6. Information systems
7. Organizational culture and leadership
8. Physician integration
9. Governance structure
10. Financial management

Of particular interest to this model is the Structure domain that relates information systems, relationships between providers and coordination across settings and levels of care in health systems integration. These structural dimensions at the organizational level, in the aggregate, contribute to system level capacity for integration.

Integration architecture, as depicted in Figure 4, is a synthesis of the frameworks covered in Section 2.2.2 (p.23). Here, integration architecture describes the foundational characteristics and capabilities, structures and processes, upon which an integrated healthcare system is based. The architecture of integration within a system is determined by its degree, breadth and type, in the context of the systemic and normative integration structures and processes in the system itself. The model was developed using Kodner's (2009) archetypal summary of integrated care literature with some notable amendments. Kodner's "degree" of integration, which is nominally used here, is derived from Leutz's (1999) "levels" of integration subsequently named "intensity" by Shaw et al. (2011), and describes a continuum from linkage and collaboration to full integration of health entities within a network of care. Degree of integration is often determined by and descriptive of the type of governance arrangement between the integrating entities in the system. Here the Luetz model is augmented with two additional measures suggested by Ahgren & Axelsson (2005), a zero point called full segregation, and cooperation, representing actions more oriented towards joint action than coordination (see Figure 2.).

The likelihood of a closed, fully segregated network existing in a complex healthcare system is unlikely. A fully integrated healthcare system is also unlikely given the challenges of merging social service and clinical care goals, however it may be contemplated for care to a small subset of people with severe disabilities (Leutz, 1999). Both are included, however unlikely, for completeness of the model. A complex health network, such as a regional healthcare system, will have a vast array of sub systems, such as long term care or mental healthcare, in varying degrees of integration along this continuum.

System integration “breadth” in the model, also referred to as “form” by (Macadam, 2008), refers to the structural arrangement of entities within the integrating network. Macadam and others recognize only two forms of integration (vertical and horizontal), however the literature reveals two additional forms which additively provide a more comprehensive description of the spectrum. Vertical integration affiliations between two or more providers generally refer to health entities providing different types of services aligning along the care continuum. That is entities from, for example, primary care, home care, acute care, and long term care aligning delivery of services. This phenomenon is commonly associated with mergers or acquisitions of health entities, often with common ownership (for example Kaiser Permanente and Inter Mountain Health Care in the United States) and formal fiscal and clinical accountability or contractual obligations (Shortell et al., 1994). Patients enter the vertically integrated system through corporate primary care facilities and are directed to hospitals which are owned by the same corporation. Less so with Canada, however, where public ownership of healthcare assets is the predominant model.

Horizontal integration does commonly occur in Canada, when health entities providing similar services form an alliance, such as a network of physicians, or pharmacists or long term care facilities. Inter-sectoral integration has been used by some researchers synonymously with horizontal integration, however in the context of this model, inter-sectoral integration refers to alliances between a health entity and organizations or networks outside the healthcare sector such as housing, social services and the environment. Virtual integration, first introduced as a variant of vertical integration but without the common ownership (Conrad & Shortell, 1996), refers to networks of entities governed by formal or informal contractual relationships (Goodwin et al., 2004) which can be vertical, horizontal or inter-sectoral. None of these categories are mutually exclusive.

System integration "Types" generally refer to "buckets" of common activities in support of healthcare service delivery. Kodner (2009, p.11) identifies the following:

1. Functional – shared or coordinated administrative and support activities such as procurement, finance & information technology;
2. Organizational – relationships between organizations, governance systems, coordinating structures;
3. Professional – provider relationships within and between organizations;
4. Service or clinical – coordination of services and care across time, place and discipline;
5. Normative – shared mission, vision, values and culture across organizations in the system; and
6. Systemic – alignment of policies, rules and regulatory frameworks.

Contandriopoulos and colleagues' (2003) typology framework includes funding and information systems, whereas in this model they have been subsumed under the functional category; their location less important than the ability of the model to accommodate them logically in the correct construct grouping. Conversely, normative and systemic integration, which are included in various models' "types" of integration (Contandriopoulos et al., 2003; Fulop et al., 2005; Kodner, 2009; Nolte & McKee, 2008), are not grouped with types of integration in this model.

Normative integration refers to the shared mission, values and culture in the system, systemic to the policy environment which supports other types of integration. Both are placed within the integration architecture but have such a diffuse impact on the degree, type and breadth of integration achieved that they are not assigned to any one construct but are separated to denote the pervasive influence each has on the selection of an appropriate integration architecture. For example, the governance and funding (systemic integration) of a network of primary care providers influences the breadth of horizontal integration amongst the physicians and multi-disciplinary team members. A co-governing troika representing physicians, the regional health authority and health ministry provides oversight to the use of public funding for the network under examination in this study. It also influences the degree of integration possible, the types of integration, and the breadth. All are inter-related, though the literature quantifying that influence is scant.

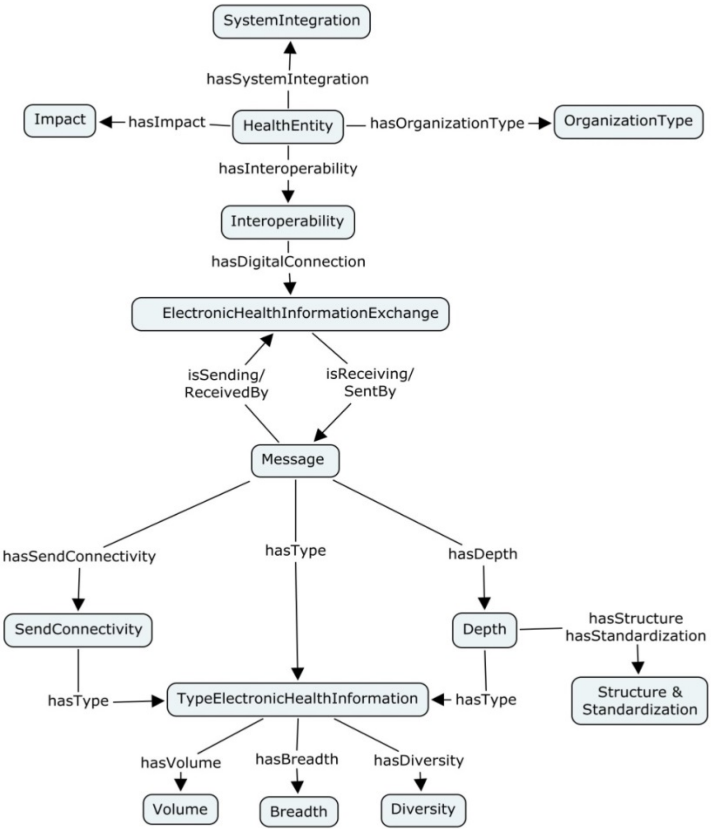
Rather than nested, as suggested by Macadam and others, integrating mechanisms in health are complex interventions which occur within a complex system characterized by “nonlinear dynamics and emergent properties” (McDaniel & Driebe, 2001, p.12). Thus the integration archetype is not layered or nested, but is non-hierarchical and adaptive, and may include many components of the archetype simultaneously. There is no one optimal model but a matrix of constructs which can be combined to build a representation of the integration architecture that facilitates care in any part of the system. Seamless and integrated care arises from the right combination of organizational processes and structures, and the integrating architecture. No one system has the same architecture, nor operational domains or performance expectations; it is a reflection of the heterogeneity in populations’ health status, expectations of wellbeing, the available resources, infrastructure and policies to address healthcare needs.

Accordingly, there are no benchmarks, floors or ceilings on the level of integration required to achieve system goals. To paraphrase Ling (2012, p.82) integration “is a space rather than a plan…a broad spectrum of possible courses of action”. Thus traditional research methods such as randomized controlled trials are not only not feasible but unlikely to account for the context and dynamism of such a system; this will be reflected in the methods of this study. Furthermore to determine whether an integration architecture is delivering value, one must turn to analyzing processes which are believed to impact integration in order to identify significant correlations. The focus in this study is on interoperability as measured by health information exchange; a framework to understand and measure this construct and focused on technical interoperability is now presented.

3.2 Measurement Framework for Regional Electronic Health Information Exchange and Healthcare System Integration

Deconstructing the components of technical interoperability in the healthcare domain will contribute to the design of a data collection tool and scoring matrix to measure and report electronic health information exchange. Forthwith, the *process* of electronic health information exchange will continue to be referred to as such; however eHIE will be used when referring to the *indicator* for electronic health information exchange. An informal conceptual model of electronic health information exchange, developed using IHMC ® CMap Tools (v5.04.02, Florida institute for Human & Machine Cognition) is used to represent the interoperability measurement for this research study (Figure 5).

Figure 5. Conceptual Model of Electronic Health Information Exchange and System Integration



It provides a visual representation of interoperability constructs derived from the literature review and framework, such as a message with Depth, and a related concept called TypeElectronicHealthInformation (referring to categories of clinical information) that has Volume, Breadth and Diversity. Naming conventions for the conceptual model and the natural language explanation refer to concepts or classes (using upper case nouns with spaces removed i.e. HealthEntity in the rectangular boxes) and properties (denoted by lower case verbs and a related concept i.e. hasInteroperability) which describe the relationship between two or more concepts. The rationale and derivation of each deconstructed component in the model will be explored in the next section.

3.2.1 Electronic Health Information Exchange Model Components

Within a regional healthcare system numerous health entities contribute to the delivery of care to patients/clients. A health entity refers to any individual, group of individuals or organization, with a unified governance structure, which provides care in a healthcare system and has common electronic health information systems. Categories for the purpose of this study are provided in Table 5.

Table 5. Categories of HealthEntities

HealthEntities	Categories
Hospitals	Teaching, Community, Small, Complex Continuing Care/ Rehabilitation, Mental Health
Primary Care	Solo Practice, Group Practice, Family Health Group, Family Health Team, Family Health Network, Comprehensive Care Model, College Health Services, Community Health Centre, Government Service
Physician Specialist	Solo Practice, Group Practice
Diagnostic Services	Imaging, Laboratory
Residential Care	Long Term Care, Nursing Home, Palliative Care
Community-Based Health Services	Community Counselling, Mental Health Clinic, Pharmacy, Sport Medicine Clinic, Treatment Services
Community Care Access Centre	Regional community-based healthcare services broker
Public Health Unit	Publicly funded organization delivering regional population health and wellness services
Emergency Medical Service	Ambulance and first responders

A health entity might be a solo family physician, a laboratory with multiple locations, or a group of registered health professionals providing healthcare services in the community. In our model, a regional healthcare system has HealthEntities delivering a large majority of their care to patients/clients within geographic proximity to facilities and care providers under their care.

Referring still to Figure 5 our conceptual model focuses on technical interoperability, represented by ElectronicHealthInformationExchange, which is enabled via a digital connection with other health entities. For simplicity, the infostructure or hardware, software and associated information system architecture (Canada Health Infoway, 2006) that facilitate free flow of electronic information between health entities, and whose measurement is outside the scope of this particular study, are not included in the conceptual model.

The model acknowledges the role that Interoperability (previously defined), as well as OrganizationType (for instance hospital, solo physician or pharmacist), and Impact (a measure of the influence the provider has on information flows as a result of their supplier and client networks) might have on the HealthEntity's level of SystemIntegration. For instance, the nature and complexity of hospitals require much larger investments in a wider variety of interoperable information systems, than say an independent pharmacist. Health providers with large supplier, provider or patient bases with whom they interact such as laboratories and hospitals are more likely to impact interoperability and electronic information exchange rates than a health service in a community college. The model further differentiates between information flows (here referred to as Messages) being sent or received (isSending/ReceivedBy and isReceiving/SentBy) between HealthEntities in recognition of the fact that these flows are often not equivalent. This might occur, for example, when physicians electronically receive batched laboratory results, but submit all test requisitions in hard copy.

The model draws on concepts from Liang et al.'s (2004) measurement of system-wide electronic information exchange between hospitals in China, the following decomposes information exchange into its derivative concepts:

1. **TypeElectronicHealthInformation**: Forsythe and colleagues`(1992) categorization of formal/specific information which is contained in medical records and hospital information systems and is required for clinical decision making, is the focus of this study. Each TypeHealthInformation has sub-classes that exist for information that is both sent and received:

    i. **Diversity**: describes the array of different types of information shared electronically. It is modeled after the Canada Health Infoway Blueprint (2006) that refers to common clinical applications and is consistent with other researchers' conceptualization of clinical data categories appropriate for health information exchange. Nine information categories or sub-classes of the class TypeElectronicHealthInformation contribute to the Diversity of information being digitally exchanged. The more information exchanged the higher the Diversity

        a. Patient/client
        b. Medication
        c. Laboratory
        d. Diagnostic imaging
        e. Inpatient/outpatient

    f. Public health

    g. Referral

    h. Problem list/history

    i. Scheduling

ii. **Breadth**: refers to the ratio of other health entities with whom clinical information that should be shared is being shared electronically, to all those with whom any information could be shared (electronic or otherwise). So for instance a group primary care practice with a relationship with 200 specialists to whom the physicians collectively refer patients/clients for consultations but who are digitally connected to only 20 of them would have a Breadth of .10 or 10 per cent.

iii. **Volume**: refers to the ratio of the total amount of information that should be shared is being shared electronically, to the total volume of information that could be shared (electronic or otherwise). The information flow may be quantified in a number of ways depending upon the goals of the performance management system; in healthcare the flows of information vary considerably by information type due to a variety of factors such as IT funding, system-level strategy, and adoption by user communities. Volume is therefore restricted by the type of information being exchanged in the electronic message and ranges from zero to 100 per cent of the total information being shared.

2. **Depth**: The depth of technical sophistication for receiving digital messages is measured by the construct Structure & Standardization.

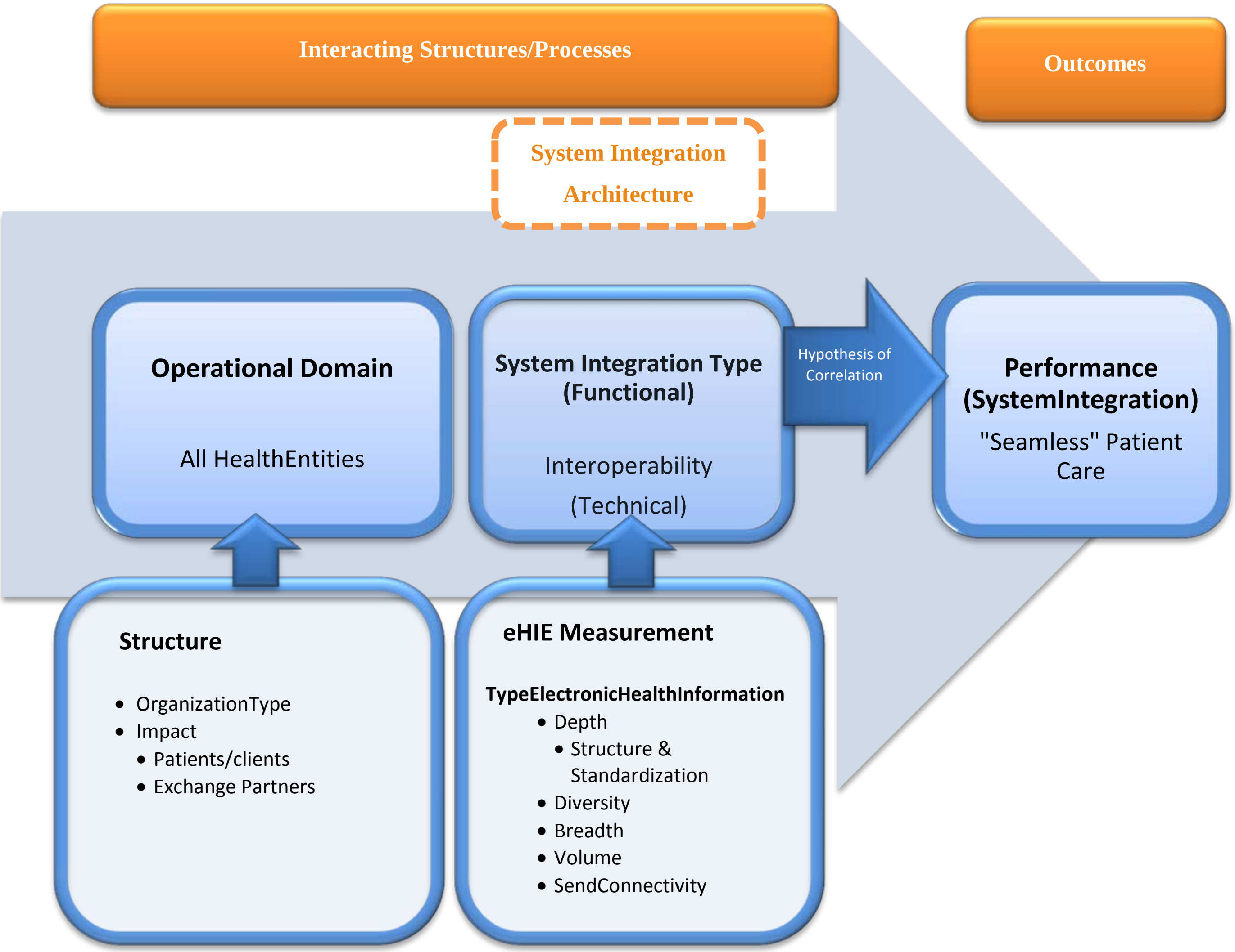
    i. **Structure** of the message refers to the syntactic interoperability of messages, which implies a common exchange model. Unstructured digital message types include such objects as free text in emails, pictures or .pdf files that require human intervention in order to integrate the data into receiving systems. In short the exchanged data is electronically transportable and machine readable, but there is no mechanism for automatically organizing the data in the receiving system. Structured data uses markup or particular formats (such as Health Level Seven or HL7, and Digital Imaging and Communications in Medicine (DICOM) in the healthcare sector). This provides a common set of rules for disparate systems to send data and receiving systems to organize it; it does not however, address shared interpretation or meaning of the exchanged data. Thus structured messages might have common rules governing which field in a receiving systems is populated with data from a particular field in a sending system, and on the format of data exchanged, for instance that dates take the format dd/mm/yyyy.

    ii. **Standardization** refers to the degree of semantic interoperability of exchanged messages. Semantically interoperable systems are able to electronically exchange data that is universally interpreted by both originator and receiver systems (and thus is correctly acted upon); it is both machine readable and machine interpretable. Tools such as controlled vocabularies like the Systematized Nomenclature of the Human and Veterinary Medicine Clinical Terms or SNOMED CT, classification systems (such as the International Classification of Diseases or ICD), and coding systems (such as Logical Observation Identifiers and Codes or LOINC) are used for shared meaning. Without standardization messages may be digitally transportable and human-readable, however they are not machine-interpretable. For instance there are multiple ways of referring to blood pressure values in EMR applications such as “120/80”, “OK”, or “under control”, but unless receiving applications are able to understand the intent of the sender they are unable to act on the information.

b. **SendConnectivity**: defines a HealthEntity’s capacity to share information on a single point-to-point basis between organizations (such as an EDI connection between a laboratory and a physician), or on a point-to-multi-point basis (such as diagnostic imaging information posted on a hospital portal for retrieval by numerous providers).

Using the health system integration framework developed in Figure 4 and conceptual measurement model in Figure 5 to derive the eHIE, an abridged measurement model in Figure 6 is proposed.

Figure 6. Framework & Measurement Model for Regional eHIE and Healthcare System Integration



Donabedian's interacting structures and processes model contributing to quality of care outcomes remains in evidence in Figure 6. The measurement model is limited to those concepts which contribute to the system performance indicator (eHIE). To ensure that all electronic health information exchanges between HealthEntities are included in the measurement, the operational domain includes all relevant HealthEntities. Structures of HealthEntities in the regional system will influence interoperability as will the OrganizationType.

Furthermore, the scale and scope of the HealthEntity’s Impact on the system, measured by the number of current exchange partners, as well as the size of the patient/client base, will also influence the system’s interoperability level. Larger organizations with many exchange partners have more interfaces across which information must flow. Similarly an organization with 10,000 patients/clients, such as a large provincial laboratory, has many more daily transactions within a regional health system than an orthopaedic surgeon in a solo practice. Lower levels of electronic health information exchange capabilities in the laboratory will have a more profound impact on a regional system’s collective eHIE performance by virtue of size of their patient/client base.

Hripcsak (2007) suggests that evaluation of health information exchange projects (in this study electronic health information exchange) can be derived from summative evaluations of individual projects. Ford, Colombi, Graham, & Jacques' (2007) “i-score” suggests that an interoperability measure is the combinatorial set of all systems key characteristics, that the average score is an approximate measure of the interoperability of a network of systems, and that gaps between the measured score and the optimal score represent opportunities for improvement. This logic will be accepted for our model with individual eHIE scores contributing to the summative eHIE to represent a regional health system’s interoperability or information exchange capacity on average. The equation derived from our framework for the eHIE will be presented in the Methods Section 4.5. Higher individual eHIE scores will identify entities in the system engaged in higher levels of electronic health information exchange activities.

Having successfully conceptualized the framework for electronic health information exchange (Research Question 1) and proposed a measure of regional eHIE (Research Question 2) both were used to guide the methodology and design of appropriate data collection tools in Chapter 4.

Chapter 4

Research Methodology & Design

This chapter outlines the methods by which the conceptual framework to measure regional electronic health information exchange and integration was used to design a consensus development process which engaged experts in hypothesizing potential metrics to measure integration based on electronic information exchange. This process informed the design, development and pilot testing of a questionnaire that quantifies inter-provider flows of digital information and their perceptions of integration, and the analysis of that collected data. Knapp (1996) suggests that evaluation of integrated services requires strong conceptualization, should build from the “bottom up” and, where possible, be collaborative; these methodological principles were applied throughout.

4.1 Research Study Design

The literature review in Chapter 2 derived a conceptual model of the relationships between electronic health information exchange and healthcare system integration. Subsequently in Chapter 3 we developed a measurement framework to theoretically support this relationship, and also devised a theoretical framework for measurement of electronic health information exchange, the independent variable eHIE. The unit of analysis for this study is a network of health care providers located in an organized healthcare delivery system, a regional grouping of health entities which provide services in the area.

Figure 7. Conceptual Map and Research Plan

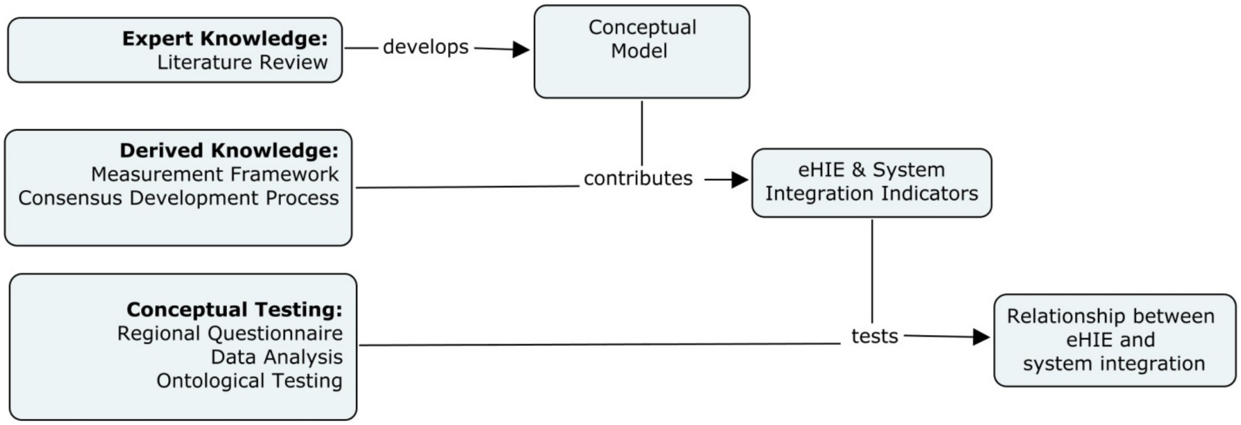


Figure 7 provides a flow chart and conceptual map of the research study design. A consensus development process allowed experts in the field to contribute their understanding of meaningful metrics of electronic information exchange that are related to regional healthcare system integration. This contributed to the development of appropriate system integration indicators related to electronic health information exchange. In parallel, a formal ontology, or visual representation of electronic health information exchange measurement concepts, entities and the relationships between them, was created to ensure the logical consistency of selected measures, to share meaning and knowledge, to facilitate expert scrutiny, and to help test the conceptual validity of our model and research assertions.

Finally, a questionnaire distributed to healthcare providers in a regional health system gathered data to populate the components of the eHIE indicator, and established the level of integration experienced by providers within the system. Statistical analysis explored the relationship between eHIE and integration at the system level. The follow sections provide more detailed descriptions of the data collection methodologies.

4.2 Consensus Development Process – Expert Measures of Integration

As noted in Section 2.2.3 there are few validated measures of health system integration. The use of expert opinion is an established methodology in health research (Kuzel, 2010) , particularly when developing indicators where there is no data or consensus available, or where there is limited evidence (Campbell & Cantrill, 2001). Consensus development processes such as the nominal group technique have a long-standing history of use in the healthcare setting, however the methodology is dependent upon the credibility of the participant experts and the methodological rigour of the process (Campbell & Cantrill, 2001). For these reasons a methodology that engaged a broad selection of experts in consensus development around appropriate measures of system integration was used.

4.2.1 Purpose

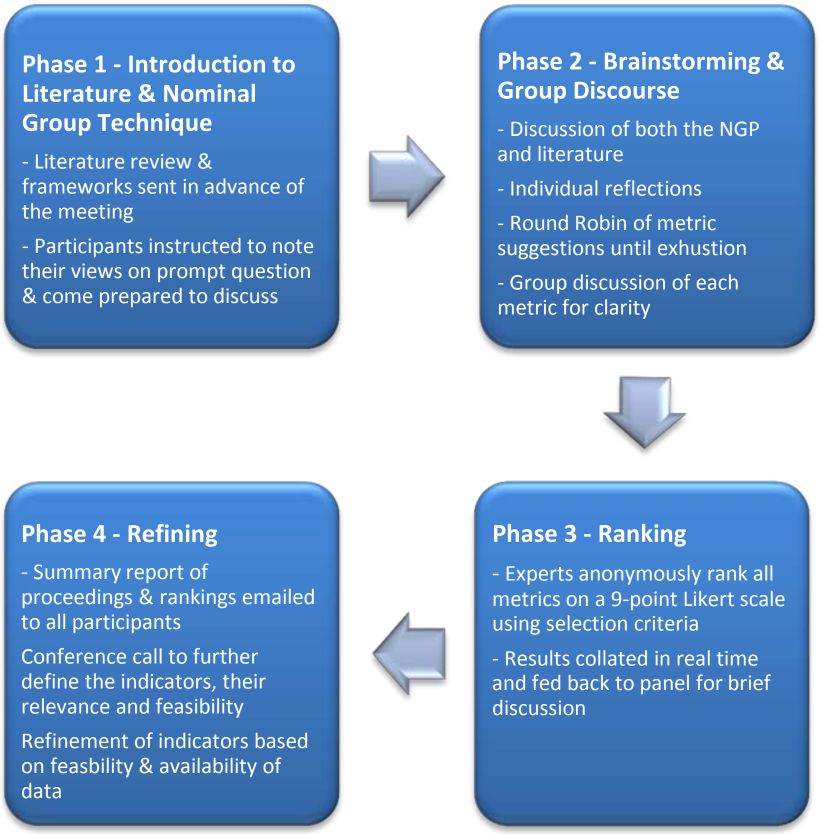
A modified, iterative consensus development process, called a nominal group technique, was used to gather an expert advisory panel's input into how system integration might be measured through electronic information exchange. The nominal group technique or process (NGT) is preferred over other consensus techniques as it allows for face-to-face discussion, and facilitates more equitable contributions from groups of participants due to its structured format and anonymous ranking process (Campbell & Cantrill, 2001). The process has been widely used in exploratory health service research and for preliminary investigations prior to more formal research methods such as surveys. In one example, valid, important and useful financial indicators in the health care sector led Pink and colleagues (2007) to use an expert panel, literature review, and survey methodology to select indicators and methods of calculation. This combined methodology produced indicators which were strongly validated by users.

4.2.2 Procedures

Experts were identified by “social acclamation”, a reasonable strategy according to Shanteau and colleagures (2002). Their experience and training gave them the ability to understand complex systems due to their relational and causal knowledge (Abernethy, Horne, Lillis, Malina, & Selto, 2005); it is this comprehensive understanding of systems which was required in this conceptually challenging performance measurement task. The participants were purposively sampled to include recognized experts from a variety of sectors and disciplines, such as primary care and public health, with a sound knowledge of the regional health system, and an understanding of electronic information systems (Van de Ven & Delbecq, 1972). Participation was also determined by availability and willingness to participate. Recommended group size for nominal group process is no larger than eight to twelve individuals (Fink, Kosecoff, Chassin, & Brook, 1984; Van de Ven & Delbecq, 1972).

Figure 8 presents the four phases of the nominal group technique through which the panel of experts were guided.

Figure 8. Nominal Group Technique Phases for Expert Panel



Ideally, consensus processes should be informed by a concise summary of existing empirically-derived data (Fink et al., 1984). Introductory materials identifying indicator selection criteria, as well as interoperability frameworks, were distributed ahead of the meeting and introduced participants to both the domain of interest through a literature review, and the procedures for the nominal group technique (see Appendix A). Participants were asked to read the introductory material ahead of time and consider the question: “What metrics satisfy the indicator selection criteria (scientifically sound, relevant, feasible and communicable), and might contribute to our goal of measuring system integration using between-provider electronic health information exchange?"

While there are no accepted benchmarks to identify when consensus is reached, consensus must be defined in advance and the more demanding the criteria the better (Fink, Kosecoff, et al., 1984). Consensus was achieved in this process, when the mean score of all participants' rankings for an indicator was greater than or equal to 7, and 70 per cent or more of the participants ranks the indicator at 7 or higher. Despite its acceptance as an established practice in performance measurement, the risk remains that expert panels in a nominal group process may reach consensus but agree on indicators that do not satisfy the measurement objective. In order to mitigate this risk the literature review provided an empirical foundation for methodological decisions.

However, we know that healthcare system measurement constructs must be clearly defined and consistently understood in order to populate performance measures with reliable data (The National Quality Forum, 2008). This is particularly important in nascent domains such as that addressed by this study, where it is necessary to decompose concepts into smaller foundational elements. In order to share this knowledge with a wider community for future validation and use, an explicit conceptualization of regional electronic health information exchange and system integration was proposed through the development of an ontology to formalize the Conceptual Model and Measurement Framework (see Figure 5). Gruber (as cited inUschold & Gruninger, 2004) defines an ontology as "a formal, explicit specification of a shared conceptualization". Gandon's (2010) definition is a little more accessible; it is as a "hierarchical organization of the relevant concepts and relevant relationships between these concepts, as well as rules and axioms that constrain these relationships" (p.4).

4.3 Explicit Modelling of Regional eHIE & System Integration Measurement

Where a knowledge base is large, complex, and distributed, or is to be systematically analyzed, it is advisable to make the information machine-readable (searchable and able to be understood by computers) through the use of a standardized and unambiguous terminology for the concepts, as well as rules or axioms to describe their constraints (Gandon, 2010; Kates, Marconi, & Mannie, 2001; Lacher & Groh, 2001; Ryan, 2006). Explicit knowledge, provided in machine-readable format such as an ontology, provides not only an accurate representation of the domain which is open to sharing but is extensible, or capable of adding new functionality and accommodating dynamic environments without substantial modification of the conceptual infrastructure, and may also be visualized in order to better communicate. In this study, the ontological approach was determined to be more appropriate than other tools such as the entity-relationship or data-flow diagrams due to its richness and capacity in describing classes, the facility to apply new classification rules across the ontology, and ability through inferencing to automatically classify any new entities added to the system, and to scale up and connect with other conceptual models.

While ontologies are common in biomedicine, there is little research into the use of upper level ontologies in health information systems (Raghupathi & Umar, 2011, p. 286), or to support healthcare performance measurement (Beyan & Baykal, 2012, p.202). People’s conceptions and viewpoints of the world are highly subjective, as is their understanding of different data that populate performance measurement models. Without shared or standardized semantic and lexical models, comparison of performance data across sectors and geographic borders is unachievable, nor can it be certain that data collection tools are gathering the right information (Orgun & Vu, 2006). The regional survey gathered data across multiple sectors; its success is measured by its potential to gather and compare data across provinces and potentially across nations. The likelihood of variance in definitions of concepts and instances is high; providing clear, unambiguous descriptions of concepts ensures that appropriate data is collected and compared.

Software applications are available to assist with the somewhat arduous task of modeling domain knowledge using an ontology. In concert with a reasoner (an ontology software add-on that uses restrictions or rules applied to concepts (or classes), relationships and properties in order to make logical inferences), an ontology is able to check for logical consistency and the inference function to identify new and potentially unexplored connections between concepts and data. This makes it a particularly potent tool for conceptualizing and modeling data exchange.

4.3.1 Purpose

The simplified framework of regional health system interoperability and integration (see Figure 6), guided by the conceptual model (see Figure 5), was formalized in an ontology. Doing so means that large performance measurement databases such as that being created in this study can be automated, that is a computer can support the collection and validation of data and its quality. The ontology is also a data visualization tool, allowing users to graphically present and interpret data. Thus the ontology we created is far more than just a taxonomy of concepts, but has practical use when linked to other ontologies or data bases for future research in this domain or other domains. The ontology formally describes a variety of inter-provider electronic health exchanges which take place in a region and which are captured in our regional eHIE measurement model. A more detailed narrative of the types of information exchange which the ontology depicts follows.

A family physician who is part of a family health team (her family health team is an instance of a class of entity called family health teams, which are subsumed under a class of entities called primary care providers) with an electronic medical record (EMR). The EMR is not conceptualized in our model; this is outside the scope of this research project, however the ontology is constructed so that it can be extended to include other components such as the EMR in the future.

The family physician sends an electronic message to another health entity (what will be explained later as point-to-point connectivity), a solo practice specialist (another health entity), in the form of an email with a referral letter attached in pdf format (conceptualized as an electronic message consisting of a particular type of clinical information and which contributes to the total volume of electronic messages which are sent from this health entity). The specialist does not have an electronic medical record but does have an internet connection, so prints out the referral letter and puts it in their paper file (characterized as an electronic message between the information systems that require manual intervention in order to capture the message due to its lack of syntactic and semantic interoperability). After examining the patient the specialist dictates a letter that he sends through the regular mail (as he does not send patient information electronically); this does not contribute to the electronic health information exchange volume although it would contribute to the total volume of health information being exchanged by the specialist. This may be the only specialist with whom the family physician is able to send referral information electronically, all other referrals are sent by fax or paper and would be excluded in our model, except for the purposes of calculating the ratio (denominator) of referral information from that health entity.

Alternately, the family physician may electronically communicate with a local hospital (another health entity) by logging into its physician portal and view online reports for patients who are being discharged into her care. She is unable to alter or change the data, nor to download the data directly into the practice EMR, but the data is received in the practice by virtue of its being available in an online digital format. The hospital would report the sending of this information as point-to-multipoint as it would be available to any authorized provider in the patient’s circle of care, the physician would report their interoperability in this exchange as receiving viewable data only, considered the most basic form of interoperability for receiving information in this measurement matrix.

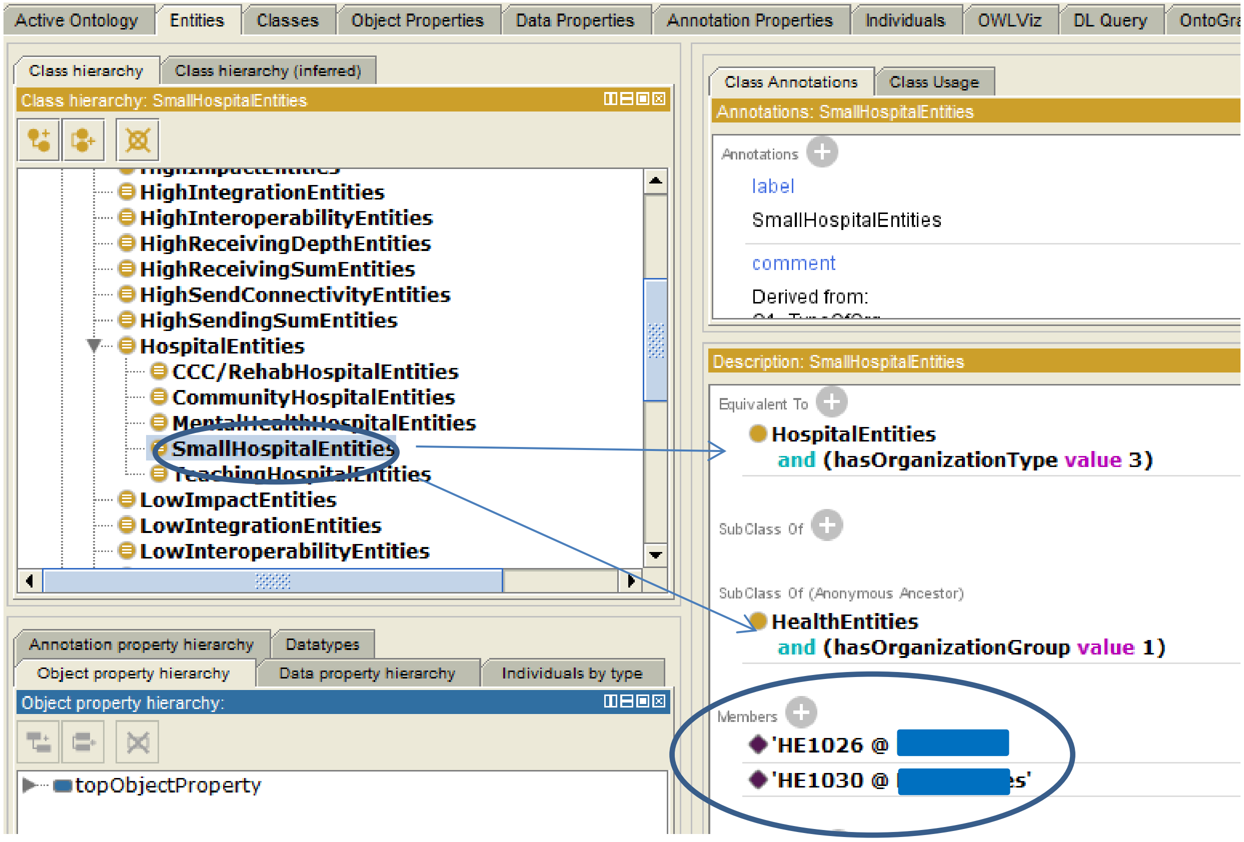
Each of these transactions represents a separate exchange, with a variety of information in different formats being received by, or sent between different health entities. For the purposes of this study we measure these exchanges for individual health entities and aggregate them as representative of the regional exchanges. All this data, collected from regional health entities using the pilot survey, populated the ontology. Clear communication of concepts, measurement models, validation of data and visualization of the domain of interest all improve the likelihood that complex concepts such as these can be communicated, understood, accepted by stakeholders and adopted for use.

4.3.2 Procedures

A formal ontological model of the research domain was developed using Protégé 4, an open-source OWL Web ontology language editor and knowledge-base framework (Stanford Center for Biomedical Informatics Research, Version 4.1.0 Beta, 2011, from http://protege.stanford.edu). HermiT Reasoner, a semantic rules engine (Information Systems Group, Department of Computer Science, University of Oxford, Version 1.3.6, 2011, from http://hermit-reasoner.com), was used to ensure the consistency of relationships between classes (for instance SmallHospitalEntities are a sub-class of Hospitals and as such will have all the properties we assign to the Hospital class), to check for errors and design anomalies in our model, to visualize the relationship between health entity's eHIE score and system integration, and to demonstrate how datasets may be linked through an ontology to logically validate results.

For example, in the proposed ontology for this domain, the class of HealthEntities has a subclass SmallHospitalEntities which is a member of hasOrganizationType which has a value of 3 (Small Hospitals) (see Figure 9) and has a property called hasOrganizationGroup which has a value of 1 (Hospitals). For expediency's sake in this study the values were derived from the questionnaire where hospitals asked to self-identify by type. Restrictions placed on classes allowed for instances to be directly imported into classes (instances) of the subclass - two small hospitals were identified in this region (listed as HE1026 and HE1030). However, with a larger collected data set containing unique data points pertaining to restrictions on the properties of the subclasses, such as number of beds or oversight by an academic institution, membership in a subclass could be inferred by a reasoner.

Figure 9. HospitalEntity subClass SmallHospitalEntities and its Axioms



label
SmallHospitalEntities

comment
Derived from:

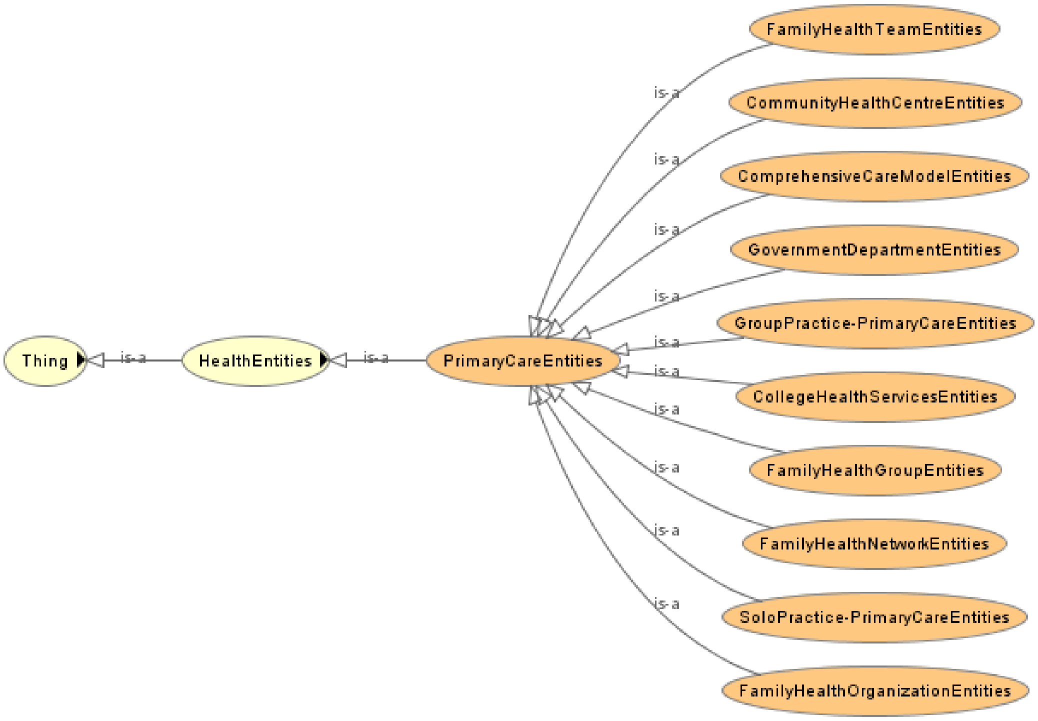
Equivalent To
HospitalEntities
and (hasOrganizationType value 3)

SubClass Of (Anonymous Ancestor)
HealthEntities
and (hasOrganizationGroup value 1)

Members
'HE1026 @ [redacted]
'HE1030 @ [redacted]s'

Ontologies may also display this knowledge-base diagrammatically, with concepts/classes and instances in boxes or circles connected by linear arrows denoting the direction of the relationship (see Figure 10).

Figure 10. Example of Ontology Diagram Format



4.4 Collecting Pilot Data Using a Regional Electronic Information Exchange and Integration Questionnaire

In exploratory research, the development of a theory or framework generally leads to empirical testing (Chwelos, Benbasat, & Dexter, 2001) and questionnaires are the most commonly used tool for gathering data in field studies (Hinkin, 1995) such as the one proposed here. While self-report surveys are noted to have "lower fidelity", they by contrast have "higher bandwidth" and allow the collection over a wide breadth of data (Gonyea, 2005, p.74). They are often the only practical way to obtain certain types of information, as is the case in this study where progress towards regional electronic information exchange must necessarily capture both electronic and non-electronic flow (eliminating the possibility of using system data logs). This ability to reliably gather a broad array of “high bandwidth” information from a variety of different organizations in various sectors using a consistent data gathering instrument is required for what is believed to be the first large-scale measurement of electronic information exchange in a healthcare region. The anecdotally wide range of information technology adoption levels amongst healthcare providers in the region, and lack of an existing database further supports this approach.

4.4.1 Unit of Analysis

The unit of analysis for this study was a network of health care providers located in an organized healthcare delivery system, a regional geographic grouping of health entities which provide services in the area. Health regions have become increasingly important geographic units for collecting and reporting data (Statistics Canada, 2007) and for developing health information systems (Adler-Milstein, Landefeld, & Jha, 2010; Mäenpää et al., 2009). Furthermore, the delivery of health services is generally conducted on a local or regional basis in Ontario.

In one LHIN, the local hospitals within the region accounted for 84.3% of residents’ separations (completed cases treated in hospital which resulted in a discharge, transfer to another hospital, death or patient/client initiated sign out). Local primary care services accounted for over 90% of the residents’ needs and more than half of the tertiary/quaternary separations (Name withheld, 2006). The Canadian Medical Association (2010) estimates that more than 85% of care occurs “at the community level” (Canadian Medical Association, 2010) and suggests that encouraging IT adoption requires a focus on local providers. Furthermore, experts have started to advocate for greater emphasis on the use of technology to support local or regional care networks rather than national interoperability (Rozenblum et al., 2011). For this reason the LHIN or regional health network was the unit of analysis for this study and the boundary for our sample population.

The Auditor General of Canada quoting Canada Health Infoway, reports that 2,000 health care transactions, such as laboratory tests and hospitalizations, occur every minute in Canada and states that "many are quite complex and all involve documentation and information flow" (Office of the Auditor General, 2009, p.7). By extension we assumed that all healthcare providers in the region under study were engaged in health information exchange. Respondents surveyed were asked to quantify these exchanges by responding to questions designed to provide data which operationalized the framework, measurement model and ontology. Respondents were asked to assess the region's level of health care system integration, the level of integration between their organization and the regional health care system generally, and how their organization's level of electronic information exchange affected their perceptions of integration within the system.

4.4.2 Development of the Questionnaire Instrument

Using the literature review, framework, conceptual model and research questions, a single questionnaire was designed for administration to health service providers across the regional health system. The Survey Research Group at the University of Waterloo was contracted to assist with the development and design of the questionnaire and provided oversight for its distribution both in hard copy, for use by mail or fax, and online using Sensus Web ® (Sawtooth Technologies, Version 4.2, 2005) for respondents who preferred to complete the survey electronically. The SRC assisted with the electronic distribution of the survey, as well as data cleaning and aggregation.

Development and testing of the questionnaire content and format was an iterative process. Vest & Jasperson (2010, p.302) suggest that measures of health information exchange should be dictated by architectural strategy, notably how organizations "share, store, control and access information". However, in order to achieve the previously mentioned "high bandwidth" that gathers data from a broad range of providers (many of whom have little to no technical understanding of information technology architecture), the questionnaire needed to be technically agnostic. That is, it should require no specialized knowledge of the information systems in use in the organization, merely knowledge of the types of clinical information being sent from and received by the organization.

Furthermore, initial discussions with key informants and experts participating in the consensus development process determined that while some of the concepts might be better understood by those with some background in information and communications technology, the logistics of accessing those staff would be difficult in most cases and impossible in some (for instance in the case of a single physician office with outsourced computing support). Therefore, the questionnaire was created with a broad, lay respondent population in mind with iterative design and redesign of questions to ensure they were consistent with the framework. Where possible jargon was avoided and instructions made as clear as possible without contributing significantly to the length of time to complete the survey. Constructs were simplified yet still matched to the framework and ontology, and questions recast so as to be appropriate for all potential respondents.

The questionnaire was designed in close consultation with Survey Research Centre experts and informed by previous research, to collect three types of information:

1. Demographic Information and Consent. After an introduction to the project, an expression of gratitude for participation, and confirmation of name, organization name, and address

information, participants are given confidentiality information, information on accessing summary information from the research and an explanation of terminology;

2. Factual information about the respondent and the entity they represent (Questions 1-2, 16 & 17), the entity's electronic information system capability (Questions 3-4), and the health entity's clinical information exchange activities (Questions 6a- 6c, 7-12);
3. Respondent attitudes towards and opinions about electronic information exchange (Questions 5 & an open-ended Q 18 that provided an opportunity for respondents to provide any feedback), and the levels of integration within and with the healthcare system or LHIN (Questions 13-15).

A matrix of the questions and the constructs from the measurement framework (Section 3.2) and reference sources if available, is outlined in Table 6.

Table 6. Matrix Relating Questionnaire to Measurement Framework

Construct	Question No.	Included in eHIE calculation	Description	Purpose	Relevant Source
Health Entities	1	N	Confirmation of health entity type	Triangulation with purchased provider lists. Identifies healthcare discipline for each organizational respondent and sector of the health entity	Various government documents, websites, purchased database, organization membership lists, key informants
Health Entities	2	N	Respondent role/title	Identification of organizational respondent and role	
Health Entities	3b	N	Use of electronic information systems for medical records	Consistency check – allowed for skip opportunity to Q5 Attitudes to electronic sharing of information	
DigitalConnection	4	N (Imputed from eHIE score>0)	Whether health entity is exchanging electronic information	Consistency with following questions & skip opportunity to Q5, integration questions and exit for those without electronic records	

Construct	Question No.	Included in eHIE calculation	Description	Purpose	Relevant Source
HealthEntities	5	N	Respondent attitudes to electronic information sharing.	Consistency check between attitude and action (Q6 sharing of electronic information).	
TypeElectronicInformationExchanged	6	N (Imputed from eHIE score>0)	Whether entity is sending/receiving electronic information	Identifies all relevant types of information being exchanged and with what type of provider. Electronic health information systems have developed in modules, often by discipline or information type. This typology of information is used for Q7-12 and facilitates skip logic for online respondents	(Adler-Milstein et al., 2008; Canada Health Infoway, 2006; Forsythe et al., 1992; Gorman, 1995; Powers, 2008)
SendConnectivity	7	Y	Connectivity dimensions between organizations include point-to-point sharing across entities, and the highest level which is asynchronous sharing on a point-to-multi-point basis	Entities may have different interoperability based on the type of information shared. They will send clinical information for the use of either one health entity or many entities. Also contributes to the imputation of syntactic interoperability	(Devitt, 2009)

Construct	**Question No.**	**Included in eHIE calculation**	**Description**	**Purpose**	**Relevant Source**
Depth/Structure & Standardization	10	Y	Identifies the gross level of syntactic &semantic interoperability of receiving systems	Liang et al. (2004) refer to this construct as measuring the level of sophistication of the messaging between partners, and refers to three levels namely file-to-file, application-to-application and a coupled work environment. For interpretation by a lay audience four constructs were developed, “viewable” (non-interactive applications), “viewable & editable” (interactive web-based applications), “automatic”(machine readable & interpretable), & “manual” (requires human be exchange i.e. batch files, pdfs)	(Liang et al., 2004; Massetti & Zmud, 996)

Construct	Question No.	Included in eHIE calculation	Description	Purpose	Relevant Source
TypeElectronicInformationExchanged/Volume	8, 11	Y	Estimates the ratio of the total amount of information which might be exchanged [sent or received] electronically to that which is exchanged electronically	The volume of information flowing electronically will differ according to whether it is being sent or received, the type of information and the structure & standardization of the message	(Liang et al., 2004; Massetti & Zmud, 1996)
TypeElectronicInformationExchanged/Diversity	7, 8, 9, 10, 11, 12	Y	Describes the array of different types of information sent or received electronically	Modeled after the Canada Health Infoway Blueprint (2006) that refers to common clinical applications which share such information as public health data, medication information, diagnostic imaging and laboratory information	(Canada Health Infoway, 2006; Gorman, 1995; Liang et al., 2004; Massetti & Zmud, 1996; Powers, 2008; J. Walker et al., 2005)
TypeElectronicInformationExchanged/Breadth	9,12	Y	Quantifies the level of information actually sent and received between an entity and other entities in the health system, and what might be sent or received	Provides an understanding of the ratio of the entities in a system which are sharing information electronically	(Liang et al., 2004)

Construct	Question No.	Included in eHIE calculation	Description	Purpose	Relevant Source
Impact	16,17	Modifier	Aggregate “score” derived from analysis to provide 15 meaningful cutpoints for total number of patients/clients served & 10 cutpoints for total number of providers with whom information exchanges occur in any format. Impact is factored separately for priority investment decision-making. Scores are ordinal out of 25.	Provides a modifier for the eHIE to indicate the impact a HealthEntity has on the system-level electronic health information exchange. More networked or larger providers will have greater impact on interoperability than smaller i.e. a large public laboratory may have a greater impact on system than a solo physician’s practice	
Integration	13,14,15	Dependent Variable	Each question is intended to address slightly different constructs to uncover differences in integration conceptualization that relate differently to clinical information exchange. Q13 refers to integration of the entire regional system, Q14 relates to the individual organization’s integration and Q15 focuses on integration resulting from information HIE	Conceptualization of perceived integration by health service providers has been used to deconstruct integration. Global perceptions of integration related to its related factors, including information technology have been used in previous studies	(Batterham et al., 2002; Triska et al., 2005)

All of the questions in the questionnaire except three were closed-ended. The three open-ended questions #2, #6b, #6C and #19 allowed respondents to describe their role or title, describe other types of entities with which they shared information electronically outside those in the matrix, or offer their opinion on the survey and electronic information exchange in their region. Where there was a need to discriminate between various levels of construct responses, a four-domain continua (“0 – <25%”, “25 - <50%”, “50 - <75%”, and “75 – 100%”) using a direct estimation scale was modeled after Labkoff & Yasnoff"s (2006) evaluation of health information exchanges in four U.S. states. The scales measured percentage of providers exchanging information in Questions 8, 9, 11 and 12, and an adjectival scale (“not at all integrated”, “slightly integrated”, “moderately integrated” and “fully integrated”) to measure level of perceived integration with the system, in Questions 13, 14 and 15 (Streiner & Norman, 2008).

Question 10 delineated the level of standardization and semantic integration of received information according to whether it was “viewable” or able to be viewed online using tools such as portals or viewers, “manual” or requiring human intervention in order to move received files or data into the receiving information system, or “automatic” where received files were automatically available for use by the information system and did not require human intervention.

In each of Questions 6 – 12, information categories were fashioned after the Canada Health Infoway Blueprint (2006) that refers to common clinical applications which share such information as public health data, medication information, diagnostic imaging and laboratory information. As with the National Quality Forum performance measures for electronic healthcare information systems (The National Quality Forum, 2008) the broad categories of data could be broken down into more granular elements (for instance, lab results) to provide a greater level of understanding of the information being exchanged, however the scope of the project and limitations imposed by the maximum length of time to complete the survey precluded this.

4.4.3 Pretest, and Face & Content Validation of the Questionnaire

The data collection instrument was pre-tested for content validity, clarity and structure with a purposive sample (12) of potential participants from the sample population including: two primary care physicians, a lay administrator from the long term care sector, one physician director from a student health service, two nurse directors from student health services, a chief technology officer from a public health unit, a chief technology officer from a hospital, a health information manager from a complex continuing care hospital, two physicians from multi-location practices, a pharmacist, a laboratory manager, a manager of an imaging facility and a receptionist working for a physician specialty practice.

Where possible the test of the paper questionnaire was conducted in person using cognitive interviewing techniques (Willis, 1999) to ensure clarity and comprehensibility, with the respondent performing a talk-aloud description of their thoughts and concerns as they completed the survey. Surveys were also completed by fax with no support other than the proposed introductions to questions as they would appear in the survey to confirm legibility, logic and clarity of language. Based on the feedback from these interviews and returned surveys, further iterations of the survey were refined and re-tested. Once the questions were finalized the questionnaire was programmed into Sensus software version 4.2 (Sawtooth Technologies, Northbrook, IL) on the Survey Research Centre host server for the online survey.

As face and content validity of the questions had been confirmed through input from subject matter, domain and survey research experts, as well as from pilot testing, the online version was tested by local academic staff not associated with the research but familiar with the project. The online testing included restrictions of blanks, skip logic, question masking, formatting on various screen sizes and operating system compatibility, instructions to respondents, the user interface, measures of time to completion and any other factors that might affect the response rate. On the advice of the Survey Research Centre's experts and feedback from the field, the questionnaire was adjusted in order to comply with the requirement that it take less than 10 minutes to complete. The Survey Research Centre advised that longer questionnaires impact negatively on response rates with busy healthcare providers, particularly physicians, and this was confirmed by pilot testing. This challenge impacted the number and content of the questions, and thus narrowed the scope of the project to focus almost exclusively on the interoperability construct at the expense of more detailed demographic information on entities or details of their integration activities.

4.4.4 Sample Population

The region selected for pilot the survey is located in Ontario, Canada. In 2006, legislation introduced by the provincial government established fourteen local health integration networks (LHINs) determined by geographic region and population. As recognized healthcare systems with the goals of providing policy support for integrated health systems, improving health care delivery and responsibility for the outcomes, service quality and financial health of many providers within the region, the LHIN and its boundaries provided a natural constraint for the regional scope of the research study. Furthermore, informal discussions with healthcare providers in the location indicated that there was broad recognition of the LHIN as a recognized geographic entity associated with integration efforts.

Entities were loosely defined by those identified in Canada's Health Infoway Electronic Health Record Solutions Infostructure Blueprint as "points of service" (Canada Health Infoway, 2007, 2009). The preliminary list of entities includes community care access centres (CCACs), public health units, pharmacies, diagnostic imaging facilities, laboratory facilities, primary care physicians' practices, specialists' practices, hospitals, community health centres, family health teams and other primary care centres, and long term/nursing care homes. While not specifically referred to in the Infoway Blueprint, long term care facilities are an important component of the continuum of care for Canada's aging population and thus were included in the study as were emergency medical services. Furthermore LHINs fund palliative care facilities as well as some community mental health providers; for completeness and due their active involvement in clinical care delivery these organizations were also included.

An aggregated list of the provider groups included in the population sample is included in Table 7.

Table 7. Census List of Regional Health Entities in the [LHIN name withheld]

Category	Total Population	
	Count	Freq.(%)
Hospital	8	1.5
CCAC	1	0.2
Primary Care	176	33.9
Physician Specialist	167	32.2
Laboratory	5	1.0

Category	Total Population	
	Count	Freq.(%)
Diagnostic Imaging	5	1.0
Pharmacy	98	18.9
Public Health	2	0.4
Nursing Home/Long Term Care	31	6.0
Community Health Services	21	4.0
Hospice/Palliative Care	3	0.6
Emergency Medical Services	2	0.4
	519	100

It is important to note that corporate health entities with multiple locations were only counted once to avoid over-representation of one organization's information technology strategy. Franchises of for-profit corporate health entities are less likely to have a single corporate information technology strategy and were counted separately. LHINs are not direct service providers themselves and do not require clinical information (as defined in Section 3.2.1 specifically formal/specific information contained in medical records and hospital information systems related to individual patients data, population data and logistic information), thus were not recognized as a health entity for the purpose of this study and were not surveyed.

4.4.5 Sample Recruitment & Questionnaire Distribution

There was no known complete list of health service providers, as outlined above, in the LHIN under study. Therefore a number of overlapping but incremental sources were used to create a database of potential respondents who operate within the regional health system's boundaries. This resulted in an aggregate list of 1,224 regional health service providers who are primarily funded by the Ontario

Ministry of Health and Long Term Care and/or whose roles and responsibilities require access to individuals' clinical information for service delivery, care planning or decision making. A commercial vendor provided a base roster of names which was cross-checked and augmented with data from the College of Pharmacists, the College of Physicians & Surgeons of Ontario, the Ontario Hospital Association, the Yellow Pages ®, the LHIN and CCAC records. Through induction and discussion with phone contacts we were able to identify individuals who practiced as part of a larger corporation, multiple-locations of single corporations, and providers who were deceased or who no longer practiced in the area, in order to reduce the list to the final population of 519 health entities in the region.

All potential respondents were contacted by phone using trained research assistants who followed a recruitment script developed and progressively modified to suit the circumstances of each provider group (Appendix B). The information provided to respondents on the phone varied according to their receptivity; those verbally agreeing to participate were asked to identify a single representative capable of responding on behalf of the entity, and to indicate their preference for receiving communications regarding the project (phone, fax or email) and completing the questionnaire (mail, fax, or online). Those requiring more information about the project were either referred to the author or sent to the project website (www.meie.uwaterloo.ca).

Questionnaires were distributed to all identified organizational contacts and data collected via fax, mail (included a stamped, addressed return envelope) and online. To avoid low response rates that might increase the likelihood of non-response bias or attracting respondents atypical of the sample population, a maximum of three reminder emails, faxed surveys or phone calls were made (Asch, Jedrziewski, & Christakis, 1997). There is some evidence that incentives are effective in improving response rates to surveys (Iarossi, 2006). VanGeest and colleagues (2007) determined that financial incentives were effective in improving physicians' survey participation. Given the high proportion of physicians in the population, a gift certificate to a national retail coffee shop was offered to all respondents returning completed questionnaires. Final survey data were cleaned and aggregated by Survey Research Centre staff. Call backs were made as necessary to confirm missing or outlier data as needed.

4.5 Calculation of eHIE indicator & Analytic Plan

The following *a priori* ordinal scoring system was used to rank data collected using the regional health information exchange questionnaire to measure the dimensions of the framework outlined in Table 6.

Table 8. eHIE Scoring Rubric

		Points Assigned Per Response					
Q#	Description of Variable and	0	1	2	3	4	Score Range
7	SendConnectivity – Sent information [Respondents are able to record multiple responses for each type of information i.e. can send information to an individual organization as well as to networked organizations]	No connectivity	To one entity $[7_1]$**	To multiple entities $[7_2]$			0 - 27
8	TypeElectronicInformationExchanged/ Volume – Sent [Single response restriction]	No connectivity	0 - <25% $[8_1]$	25 - <50% $[8_2]$	50 - <75% $[8_3]$	75-100% $[8_4]$	0 - 36
9	TypeElectronicInformationExchanged/ Breadth – Sent [Single response restriction]	No connectivity	0 - <25% $[9_1]$	25 - <50% $[9_2]$	50 - <75% $[9_3]$	75-100% $[9_4]$	0 - 36
10	Depth/Structure & Standardization – Received information [Respondents able to record multiple responses, but average score for each type of information only recorded then summed]	No connectivity	Viewable $[10_1]$	Manual $[10_2]$	Automatic$[10_3]$ OR Viewable & editable $[10_4]$		0 - 27
11	TypeElectronicInformationExchanged/ Volume – Received [Single response restriction]	No connectivity	0 - <25% $[11_1]$	25 - <50% $[11_2]$	50 - <75% $[11_3]$	75-100% $[11_4]$	0 - 36
12	TypeElectronicInformationExchanged/ Breadth – Received [Single response restriction]	No connectivity	0 - <25% $[12_1]$	25 - <50% $[12_2]$	50 - <75% $[12_3]$	75-100% $[12_4]$	0 - 36

**Questionnaire number and Information Type subscript identifier in brackets i.e. $[7_1]$, means information is being Sent "to one entity". In the eHIE calculation following this is further amended by another subscript denoting the type of information being exchange according to the following legend: 1=Patient/client, 2= Medication, 3 = Laboratory, 4 = Diagnostic imaging, 5 = Inpatient/outpatient treatment, 6 = Public health, 7 = Referral, 8 = Problem list/history, 9 = Scheduling. Thus $[7_{1_1}]$ more accurately denotes Patient/client Information being Sent "to one entity".

An example is provided to illustrate the assignment of scores using a participant's response to Q7. For each of the types of information (there are nine – see legend at the bottom of Table 8 and Questionnaire in Appendix C), the respondent indicates whether they are sending that type of information "to one entity" (such as via email to one provider) or to "multiple entities" (such as the posting of information to an online portal for viewing by more than one provider). The former is assigned one point and the latter two points. It is possible that the entity is sending information in both formats and thus the maximum possible score for each type of information is three and maximum possible score for the SendConnectivity Q7 is 27 (3 x 9). Single response restrictions are applied to Q8, 9, 11 & 12, hence the maximum total score of 36 (4 x 9). Each of these questions are scored and summed then divided by the maximum total score of 198.

There are two calculations under investigation. In both, the numerator represents the sum of scores for the dimensions of electronic health information exchange as reported by the respondent entities. The assumption in eHIE_A is that all health entities should have the capacity to allow authorized users to access and exchange all of the types of health information identified in the survey. Thus the denominator equals the maximum possible score of 198 as previously mentioned.

In the case of eHIE_B, the maximum possible score for each type of information in Q7-12 used in the denominator is reduced by 11 times the total number of information types a respondent identified as being not being applicable to their organization in Q6. So, for instance, a laboratory might indicate that sending and receiving diagnostic imaging information was not applicable to their organization. The decision as to what is or is not appropriate to be electronically shared, or whether the information might be material to the care provided by one type of health entity, is influenced by the context of the organization, its business model, and the types of information required for decision making. Responses will vary by individual organizational model. This has the potential to increase the values of each eHIE_B by reducing the value of the denominator in the eHIE equation.

Hence, the eHIE is a ratio between 0 - 1 assigned to each responding entity and is calculated using two slightly different algebraic formulae (eHIE_A and eHIE_B) to allow for comparison of results:

$$\text{eHIE\_A} = \sum \left(Q7_{1_1}+\ldots Q7_{9_2}\right) + \left(Q8_{1_1}+\ldots Q8_{9_4}\right) + \left(Q9_{1_1}+\ldots Q9_{9_4}\right) + \max\left(Q10_{1_1}+\ldots Q10_{9_4}\right) + \left(Q11_{1_1}+\ldots Q11_{9_4}\right) + \left(Q12_{1_1}+\ldots Q12_{9_4}\right)/198$$

AND

$$\text{eHIE\_B} = \sum \left(Q7_{1_1}+\ldots Q7_{9_2}\right) + \left(Q8_{1_1}+\ldots Q8_{9_4}\right) + \left(Q9_{1_1}+\ldots Q9_{9_4}\right) + \max\left(Q10_{1_1}+\ldots Q10_{9_4}\right) + \left(Q11_{1_1}+\ldots Q11_{9_4}\right) + \left(Q12_{1_1}+\ldots Q12_{9_4}\right)/198 - \sum \left(Q7_1\ldots Q12_9 \text{ maximum score where } \sum Q6_1\text{-}Q6_9=\text{NA}\right)$$

Hripcsak (2007) suggests that the evaluation of health information exchange projects can be derived from summative evaluations of individual projects. This logic is extended to this study’s assessment of an individual health entity’s information exchange activities and their contribution to the regional health system’s interoperability or information exchange capacity. Higher individual eHIE scores will identify entities in the system engaging in higher level electronic information exchange activities and thus higher interoperability. The mean value of aggregated scores represents the mean health information exchange of the system as a whole. Individual indicators, their component dimensions such as sending and receiving certain amounts of a particular type of information, the expert panel’s measures of integration from the nominal group process, and health providers’ perceptions of integration from the collected data will be examined using descriptive statistics and ANOVA.

Based on the literature, a poisson distribution is anticipated for eHIE scores with many respondents reporting no or little inter-organizational electronic information exchange. For this reason simple correlation analysis was used to examine the relationship between eHIE and system integration.

4.6 Ethical Considerations & Confidentiality

All data collection from exploratory interviews and workshops, questionnaire development and distribution, and stakeholder interviews received ethics clearance from the University of Waterloo’s Research Ethics Board in accordance with protocols for research with human participants, including informed consent (see Appendix D & Appendix E).

Chapter 5
Findings

The study findings are addressed in four sections. The first will report on the outcomes of the expert consensus development process used to identify measures correlating electronic information exchange with integration. The second will present summary results of data from the regional survey used to collect data to populate the various components of the eHIE indicator. The next section will calculate system-level eHIE and integration measures, and the following section examines the relationship between the two. Finally, a formalized conceptualization of our measurement model will be presented to demonstrate its utility in specifying and visualizing the classes, properties and their relationships, to create an enduring artifact for use in future measurement research, and as a tool to prototype the logical testing and validati0n of data collected in the survey.

5.1 Expert-Derived System Integration Performance Measures

Eight experts were confirmed for one, three hour consensus development process as outlined in Section 4.2.2 (time constraints established by the participants) - seven participated. Regional representation of stakeholders and provider expertise was achieved: primary care *(n=1),* public health *(n=1),* provincial government technology and performance leads *(n=2),* regional level health services policy makers *(n=1),* Community Care Access Centres *(n=1),* and the hospital sector *(n=1).* The individuals' roles included senior policy makers in strategy and technology fields *(n=2),* physicians *(n=1),* chief technology officers *(n=2)* and chief executive officers *(n=2).*

Experts were assembled at a common location (given the time constraints an expedited process to gain agreement was believed to be more likely if the participants were able to communicate in person). Following introductions and gathering author consent (see Appendix F), and a brainstorming session regarding the results of the literature review and forthcoming process, each expert in turn was asked to suggest one metric of system-level integration that would measure the level of electronic health information exchange in that system. Each suggestion was numbered and discussed by the group for clarity; this process continued until exhaustion of new ideas was reached. Facilitated by the author, with the assistance of two research associates, the discussion and proceedings were audio recorded for future reference. This process was intended to confirm the findings as a true representation of the nominal group process, enhance credibility, and build participants' trust in the data (Guba & Lincoln, 1994).

Suggested metrics were also recorded on a flip chart as discussion occurred. A ranking sheet was provided to the experts with instructions to anonymously rank all suggested metrics (see Appendix G) using the selection parameters previously noted. The sheet used a 9-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (9). Results were collated in real time and fed back to the panel. Mean scores and the degree of agreement amongst the panel determined whether a metric was included in the list of acceptable metrics. Indicators where the mean was seven or higher and 70% of the experts ranked it seven or higher were included. The nominal group technique transcript was used to triangulate the results of the rankings; these were collated and a document circulated to the participants for two follow-up conference calls. This process confirmed the findings as a true representation of consensus. Available members of the expert panel were further engaged to provide feedback on the feasibility of the data collection tool outlined in Section 4.4.2.

Participants were able to independently conceive 22 potential indicators, iteratively amend the indicators as a group, and anonymously rank their concurrence with each one identified.

Table 9. Indicator Brainstorming & Ranking from Nominal Group Technique

Potential Indicator Description	Mean	Participant Agreement (%) (70% or more ranked 7 or over)	Consensus (Mean >= 7 AND 70% >= 7)
Percent of healthcare providers who share patient data electronically*	7.9	85.71	Consensus
Percent of eligible patients with a sentinel disease whose data is either entered into an electronic registry or whose data on their provider's system is linked to the registry	7.4	71.43	Consensus
Percent of patient demographic information which is electronically available *	7.4	71.43	Consensus
Percent of target diseases which are traceable electronically across the system (i.e. breast cancer)	7.4	100.00	Consensus
Percent of patients eligible for vaccinations in Ontario which are reported electronically to Public Health from any source (i.e. physicians, pharmacies, boards of education)*	7.1	71.43	Consensus
Percentage of information received electronically which is useful to the care process	7.0	71.43	Consensus
Percentage of abnormal mammogram information which is able to be tracked by are pathways electronically across the system (i.e. from radiologist's report to ordering physician to specialist to biopsy to OR booking)	7.1	57.14	Rejected
Percent of patients with a chronic disease whose information is available on a portal and accessible to appropriate care givers, patients and family	7.1	57.14	Rejected
Time between birth and notification of public health/physician (electronic notification will shorten the time between birth and post-partum care for neonates)	6.7	42.86	Rejected

* Indicators which were used or modified for use in the survey

** One® Mail is an email network maintained by the Province of Ontario where encrypted health information may be shared between authorized healthcare providers

Potential Indicator Description	Mean	Participant Agreement (%) (70% or more ranked 7 or over)	Consensus (Mean >= 7 AND 70% >= 7)
Percent of INR test results for post-operative joint replacement patients on anti-coagulation therapy which are received electronically by their attending physician	6.6	42.86	Rejected
Number of service providers in community of care connected by email	6.5	75.00	Rejected
Time between the creation of hospital discharge summary to the time it is received by a physician (electronic discharge summaries are received within minutes rather than days for paper copies)	6.3	57.14	Rejected
Percent of high needs, high risk patients whose information is shared electronically between providers	6.1	57.14	Rejected
Percent of referral forms exchanged electronically between providers	6.0	42.86	Rejected
Percent of reconciled medication management records available across the system	6.0	57.14	Rejected
Percent of electronic information objects which are relevant to patient care which *are* being *used* over those that *could* be *used*	5.7	28.57	Rejected
Percent of standards of care guidelines shared electronically which are followed	5.7	28.57	Rejected
Real-time electronic alerts when new information is available for high-needs patients	5.4	57.14	Rejected
Number of physicians enrolled in One® Mail**	5.3	42.86	Rejected

Percent of electronic information objects which are relevant to patient care which *are* being *shared* over those that *could* be *shared*	5.1	14.29	Rejected
Extent to which care guideline information is shared electronically and is able to be integrated into practice	5.1	42.86	Rejected
Percentage of published food inspection reports available online	5.0	14.29	Rejected

Table 9 identifies the indicators and scores where consensus was reached, and those for which there was insufficient agreement. The following list provides the indicators for which consensus was reached, and a summary of the expert panel's rationale for inclusion:

1. **Percent of healthcare providers who share patient health information electronically**. This metric was believed to measure a basic level of interoperability. Without a technological infrastructure in place, electronic information remains isolated in situ and cannot be shared. The caveat for this indicator were the many non-technical barriers that may prevent a provider from sending or receiving information electronically or developing the capability to do so, such as concerns over internet security when sharing confidential patient information and cost

2. **Percent of eligible patients with a sentinel disease whose data is either entered into an electronic registry or whose data on their provider's system is linked to the registry**:

   Some disease care guidelines have wide general acceptance, clear clinical pathways, broad involvement of health system sectors, and the need for coordination across the care continuum. Examples are breast and prostate cancer, and diabetes. Tracking the electronic exchange of information related to their path through the healthcare system would help to determine whether data is supporting seamless care delivery amongst providers

3. **Percent of patients receiving care whose demographic information is electronically available to appropriate healthcare providers.** The expert panel believed that this metric represented a fundamental level of integrated care with perhaps the greatest opportunity for measurement at this early stage of interoperability development within the healthcare system

4. **Percent of target diseases which are traceable electronically across the system.** Some diseases such as breast and prostate cancer have care guidelines with wide general acceptance, clear clinical pathways, broad involvement of health system sectors, and the need for coordinated and seamless care for both diagnosis and treatment. Tracking the electronic exchange of information would allow for systematic tracking of patients through the system, and would monitor progress towards seamless information exchange and care delivery.
5. **Percent of patients in Ontario receiving vaccinations which are reported electronically to Public Health from any source (i.e. physicians, pharmacies)**. Currently, immunization status reporting for vaccine preventable disease is not required other than for children in licensed daycare and those attending primary, elementary and high schools. The ability to electronically share this information with Public Health was seen as being an important indicator of the level of cooperation between healthcare providers in the healthcare system, as well as consistent with a growing focus on population health prevention strategies.
6. **Percentage of information received electronically which is useful to the care process.** This is a conceptually more complex metric and one which is driven by the subjective opinion of the provider receiving the information. Even measurement of health information systems audit logs to identify usage trends for certain data fields will not necessarily represent the utility of the data. While the indicator was likely not feasible, the expert panel was conscious of the vast amount of data which could be exchanged and believed that unchecked it has the potential to interfere with care by making it more difficult for providers to access relevant information .

Subsequently a summary of the nominal group process along with the quantitative rankings, means and level of agreement, as well as the summary of indicators above were shared with the participants by email. A conference call provided the participants with an opportunity to further discuss the strengths and weaknesses of each of the potential indicators. During the conference call, the feasibility of data collection for each of the consensus indicators from the nominal group process was discussed. A draft of the proposed survey instrument was circulated in advance of the meeting and experts' comments and feedback were recorded and transcribed. Recommendations included the need to "embrace simplicity" in the metric so that it was understandable, and a sharp reminder that healthcare providers' time constraints would limit their time for participation in the study. Three indicators from the consensus development process were modified and adopted for inclusion in the questionnaire based on discussion with the expert panel and the ability to gather necessary data from the participants in the survey target group. Each of the three is described below, along with its corresponding element on the questionnaire:

- "**Percentage of healthcare providers who share health information electronically**" was accepted as is. Participants determined that the response to this question, while not a sophisticated indicator of integration, would provide a macro-level indicator of the number of providers in a region participating in electronic information exchange activities. In addition, the question will allow cross-checking of respondent data (paper versions of the questionnaire) to ensure that those answering "Yes" answer positively to at least one component of Question 6 and at least on corresponding positive response in Question 7 – 12.
    - Question 4: "Does your organization send or receive patient/client information <u>electronically</u> with other health service providers or organizations?"
- "Percentage of patients receiving care whose demographic information is available electronically to appropriate healthcare providers" was modified to "**the percentage of**

providers whose patients' demographic information is electronically available for sharing between providers". As there is no central data repository for patient demographic information this ratio will be inferred from the number of providers reporting the capacity to share patient demographic information with other providers. Furthermore, whether a healthcare provider is "appropriate" or not was considered highly subjective, added unnecessary complexity at this time and was more material to data security than interoperability.

- All Question 6a: The number of respondents answering "yes" to whether or not they send or receive patient/client demographic information to any type of provider divided by the total number of respondents.

3) "Percentage of patients receiving vaccinations in Ontario which are reported electronically to Public Health from any source (i.e. physicians, pharmacies)" was modified to "**the percentage of providers capable of sending public health information to Public Health**".

   - Question 6f: The number of respondents answering 'yes' to sending public health information to Public Health divided by the total number of respondents.

The results of all three indicators will be reported in Section 5.4.1 and compared with regional eHIE calculations in order to assess their suitability as system-level integration measures related to electronic information exchange.

5.2 Survey Results of eHIE & Integration data

5.2.1 Sample Characteristics and Response Rates

Of the 519 identified healthcare entities[4] contacted by phone and email, 393 (75.3%) consented to receive the survey and provided the name and contact number for a representative capable of responding to questions about organizational information system interoperability. The remaining 129 (24.7%) declined to participate or were unable to be contacted after repeated attempts over a three month period. Of those entities who declined to participate, 25 indicated they were “too busy” (19.4%), 16 that they “don’t do surveys” (12.4%) and 13 (10.1%) that they had no internet connection or didn’t use electronic communications. Table 10 provides a complete list of reasons for non-participation; these reasons for non-response are consistent with the experience of other researchers in the health domain (for example VanGeest and colleagues (2007)).

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[4] A Health Entity is any health care service provider or organization, governed by a single corporate body and delivering clinical care in one or more locations under one or more corporate names, to individual patients or groups of patients, and where the predominant funding is from public sources

Table 10. Reasons for Non-Participation

Reason	n	% of Total
Too busy	25	19.4%
Don’t do surveys	16	12.4%
Not interested	12	9.3%
Confidentiality issues	2	1.6%
Didn’t feel their participation was necessary	4	3.1%
No internet connection	13	10.1%
Don’t have the authority to agree to participate	6	4.7%
No incentive provided	1	0.8%
Unknown/unable to contact	50	38.7%
Total	129	

Three hundred and ninety-three invitations to participate in the survey were distributed. During the initial call, respondents indicated whether they would prefer to receive and complete the survey via fax or mail (see Appendix C), or online (see Appendix H) receiving a confidential link through a directed email. Those receiving the survey via fax or regular mail were also provided with a confidential link to the electronic version of the survey.

Table 11 provides a breakdown of the modes by which surveys were distributed; then received once completed. Of the 182 potential respondents who received their survey by fax, 17 or 9.3% chose to respond electronically. Some of these respondents were reluctant to release their email addresses to the phone recruiter, but found logging in to a website to complete the survey more convenient than faxing a hard copy. In total almost three quarters of the respondents completed the online survey.

Table 11. Modes by which Surveys were Distributed and Returned

Mode	Sent Frequency	%	Received Frequency	%
Online	195	49.6	136	74.7
Fax	185	47.1	43	23.6
Regular mail	13	3.3	3	1.7
Total	393		182	

Responses were received from all of the health entity categories selected for inclusion in the survey; however, some categories (4) had unitary samples due to the small regional census. For example, Ontario health regions have only one Community Care Access Centre (CCAC); most have only one public health unit, though two or more are possible in cases where the public health boundaries breech LHIN region boundaries. There was sizeable variation in response rates by category for reasons outlined previously. The overall response rate for the survey was 35.1% (range 20 – 100) – see Table 12. Response Rate by Entity Category A description of each category is specified in the ontology index in Appendix I.

These response rates are consistent with other administrative questionnaires in the healthcare sector. For instance the National Physician Survey elicited an overall response rate from family physicians in Ontario of 19.4% and from other specialists of 17.59% (College of Physicians and Surgeons of Ontario, 2011). The Change Foundation's community survey of integrated care (2011) reported response rates from regulated health professionals at 23%, and community care service providers at 45% for an overall response rate of 31%.

Table 12. Response Rate by Entity Category

Category	Responded		Did Not Respond		Total Population	
	Count	Freq.(%)	Count	Freq.(%)	Count	Freq. (%)
Hospital	7	87.5	1	12.5	8	1.5
CCAC	1	100.0	0	0	1	0.2
Primary Care Practices	55	31.3	121	68.8	176	33.9
Physician Specialists	44	26.3	123	73.7	167	32.2
Laboratory	4	80.0	1	20.0	5	1.0
Diagnostic Imaging	1	20.0	4	80.0	5	1.0
Pharmacy	34	34.7	64	65.3	98	18.9
Public Health	2	100.0	0	0	2	0.4
Nursing Home/Long Term Care	17	54.8	14	45.2	31	6.0
Community Health Services	15	71.4	6	28.6	21	4.0
Hospice/Palliative Care	1	33.3	2	66.7	3	0.6
Emergency Medical Services	1	50.0	1	50.0	2	0.4
	182	35.1	337	64.9	519	100

Non-response bias for the survey was anticipated to be low. To test for non-response bias, those who returned a survey were divided into two groups according to whether they responded to the survey immediately (early), or required one or more prompts (late). Lindner, Murphy, & Briers (2001) suggest that non-response error can be accounted for by comparing early to late respondents (as long as the sample size of the latter is greater than 30). As there was no statistically significant difference between early responding entities (n = 98) and late responders (n = 84), and whether they used electronic information systems for organization or practice management (χ^2 (1) = .159, p

<0.690), patient's health information (χ^2 (1) = 2.441, p <0.118), or for sharing health information (χ^2 (1) = 1.205, p <0.272) we can conclude that the responses reported here are a fair representation of the population as a whole.

Table 13. Respondent Use of Electronic Information Systems & Health Information Exchange

	No		Yes	
	Count	Freq.(%)	Count	Freq.(%)
For practice/organization management i.e. billing, scheduling [Q3a]	18	10.0	162	90.0
For client/patient health information management i.e. medical charts/records [Q3b]	55	30.7	124	69.3
Electronic health information exchange with other health service providers/organizations	69	38.3	111	61.7

Only eight (4.4%) respondents identified themselves as rural health entity providers, and there was no significant difference between rural and urban entities engaged in electronic information exchange activities (χ^2 (1) = .482, p <0.487). Ninety percent (n = 180) of those responding indicated their organization or practice managed administrative functions electronically, 69.3% (n = 179) were utilizing electronic medical records to manage patient/client information, and 61.7% (n = 111) indicated that they were electronically sharing patient/client information with other health entities (see Table 13). It should be noted that the Ontario provincial ministry of health mandated electronic data transfer for new physicians submitting billing claims to Ontario Health Insurance Plan (OHIP) since 2003.

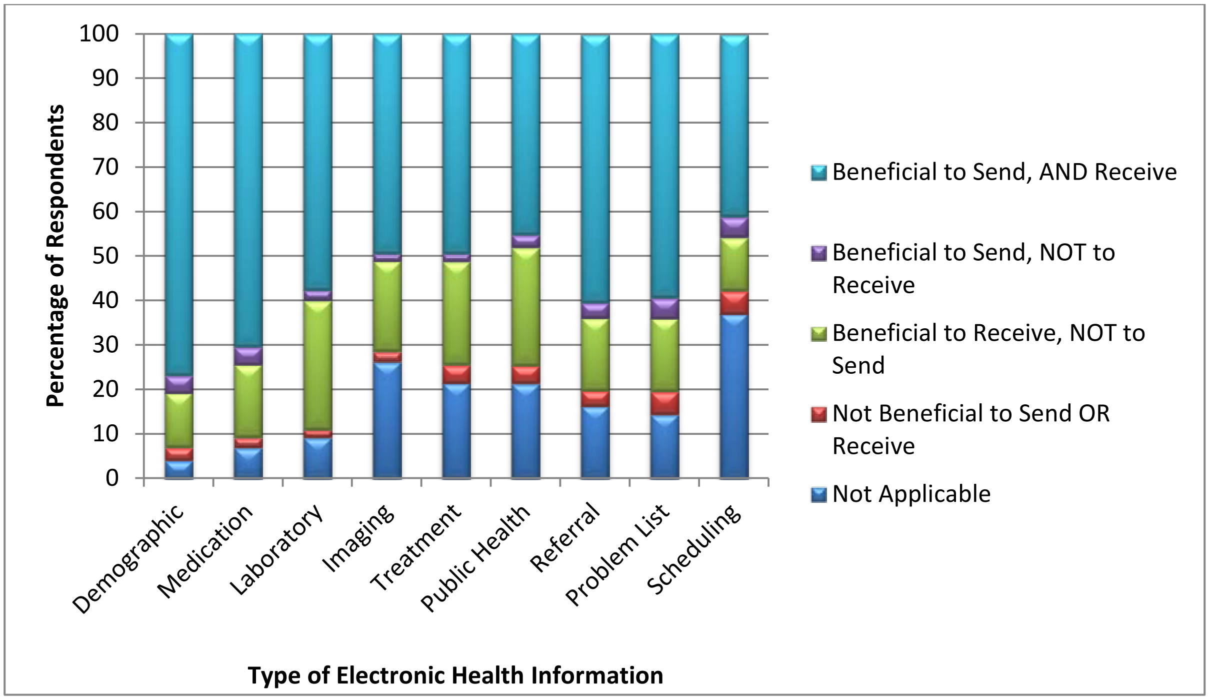
There was a highly significant association between entities having an electronic information system for clinical information management, and whether respondents exchanged information electronically with other entities outside the organization (χ^2 (1) = 30.367, p <0.001). The odds ratio was (36/16)/(32/95) = 2.25/.34 = 6.68. Thus practices which have electronic information systems were 6.68 times more likely to share information electronically with other providers, confirming that the former is likely an entrée to more sophisticated information systems use. While there was a significant difference between different health entity categories, as to whether or not they use an electronic information system to manage their clinical information (χ^2 (25) = 53.501, p <0.001), there was no significant difference between health entity types which share electronic information with other healthcare providers.

Finally, of the 69.3% of health entities which reported having an electronic information system for patient health information management, 25.2% do not share any health information with others electronically. Of the 30.7% who don't use electronic patient health information management systems, 30.8% indicate they exchange clinical information electronically with other providers. The latter was explained by the existence of hospital portals which allow providers and their authorized staff to access patient information such as lab results and medication records, or to schedule surgical procedures, and entity-to-entity exchange of clinical information via email.

5.2.2 Attitudes to electronic health information exchange

The attitude of respondents towards electronic exchange of patient health information between appropriate entities was positive, with the majority of respondents indicating that bi-directional information exchange was beneficial to their organization (see Figure 11).

Figure 11. Respondent Attitude to Electronic Information Exchange by Information Type



Respondents in general believed that it was more beneficial to receive rather than send information electronically. Unfortunately, a cross tabulation of attitudes towards electronic health information exchange and the type of information exchanged by health entity group violated minimum frequency assumptions (less than five cases per cell), therefore no statements can be made about the differences in attitude by health entity types. However, responses varied considerably by health entity category and type of information; for instance while none of the laboratories believed exchange of scheduling information was beneficial, all of the hospitals did. This is predictable given that some hospitals currently allow off-site booking of surgical and ambulatory care procedures by physicians and many are intending to adopt the functionality in the future. Laboratories, on the other hand, tend to rely on drop-in appointments rather than booked appointments and may not currently view the functionality as important in the near future and thus 75% deemed the category of information as “not applicable” and 25% as “not beneficial to send or receive” the information. Diagnostic imaging, which schedules all but urgent procedures, viewed the sending and receiving of electronic scheduling information as beneficial as expected.

Consistent with the hypothesis of eHIE_B, a percentage of health entities perceived exchange of some categories of health information was not currently applicable to their workflow and service delivery (see Table 14).

Table 14. Percentage of Health Entities Reporting Not Applicable Information Type

Type of Information	Health Entities Reporting NA (%)
Patient/client	4.1
Medication	7.0
Laboratory	9.3
Problem list/history	14.5
Referral	16.3
Public health	21.4
Inpatient/outpatient treatment	21.5
Diagnostic imaging	26.2
Scheduling	37.0

More than 70% of pharmacist and laboratory respondents indicated the exchange of diagnostic imaging was not applicable to their organizations, and more than 70% of laboratory and diagnostic imaging providers indicated that treatment information was not applicable. Responses were idiosyncratic by health entity type and rarely included all respondents in that category of health entity, suggesting that either the service delivery context i.e. certain geographies or patient needs, were impacting responses, or that education and discussion regarding possible uses of exchanged information would expand the health entities' understanding of its value. Examination of the factors impacting providers' attitudes towards electronic exchange on clinical information remains outside the scope of this particular research project but warrants further investigation in future studies. For the purposes of this study, health entities' opinions about the relevance of certain types of electronic information exchange to their particular practice were respected and allowed to influence the calculation of their individual interoperability score (in eHIE_B).

Finally, there is a moderate but statistically significant correlation between respondents' attitudes towards sharing electronic information and eHIE_A ($r_s = .204$, $p<.006$), that is those whose attitudes towards mutual exchange of health information were less positive shared less information with other health entities in the system; a lesser effect was observed with eHIE_B ($r_s = .138$, $p<.064$). It should be remembered that this metric may overstate organization's actual level of interoperability by reducing the value of the denominator. Others have suggested that attitudes are not a substantial barrier to greater electronic information exchange and interoperability (Wright et al., 2010). These results indicate that while a majority of providers see the beneficence of health information exchange, there is empirical support for the notion that those with negative attitudes towards sharing information will share less.

The following sections examine the results of the questionnaire used to gather data from the field to populate the proposed eHIE system indicators and measures of respective system integration. Data gathered from each respondent in the region is used to first calculate an individual health entity eHIE, aggregated then averaged in order to calculate a regional system eHIE or level of health information exchange. Analysis of individual eHIE scores and estimated levels of system integration from the questionnaire will help explain the relationship between the two, as will analysis with the expert-derived measures of integration and a comparison with system-level indicators of integration in common use.

5.2.3 Characteristics of Exchanged Information

Aggregate raw data from Questions 7 – 12 in the questionnaire (measuring various aspects of exchanged clinical information that we hypothesized and visualized in Figure 5) are provided in aggregate tables in Appendix J. A summary review of key insights from the tables follows and provides context for the data aside from its use in scoring and populating the eHIE numerator (Section 4.5).

Many fewer health entities are sending information for use by multiple organizations (such as through website portals or centralized databases) than those with governance and supporting infrastructure to send information exclusively to another entity. This finding is consistent with a system where information systems and interoperability are embryonic. Data exchange is negotiated between organizations with a variety of information systems which are rarely interoperable; these federated systems require interfaces in order for electronic information to flow. Patient demographic (34.8%) and medication information (42%) are more frequently sent for use by just one other health entity or organization; patient demographic (5.5%) and laboratory information (3.9%) are more frequently sent for use by multiple organizations than other types of information. Patient demographic information is common to the needs of all healthcare providers, and also uniquely identifies the client when sharing any information with other providers. Medication history is critical information in all provider handovers, and through Ontario's Drug Profile Viewer which providers information on all Ontario Drug Benefits recipients, is available to all those with access to the web-based application.

Questions 8 and 9, 11 and 12 results measure the volume and breadth of information being exchanged using quartile ranges. It is important to note that sample sizes in these questions vary by information type. Percentages are for each health entity reporting that some volume of information is being sent between them and another health entity; they are not results for the survey sample as a whole. Question 10 results (again with varying respondent sample sizes) capture the capacity of the health entity to receive structured and standardized electronic information into their systems. It is clear that most incoming information is passively received into the organization and only viewable in use rather than interactive. The second most popular method of exchange is manual, such as the receipt of emails from specialists, or batch files from laboratories that must be manually sorted and imported for use.

Before examining the information exchange scores at the system level, the next section outlines the results for individual health entities.

5.2.4 eHEI Individual Scores

No weights were purposively assigned to differentiate between the interoperability components measured i.e. message content, breadth, volume, structure or format, or other factors such as the type of digital connection. Components of the scoring matrix may therefore contribute asymmetrically to the final score for eHIE (see Table 8). Thus the volume and breadth of exchanged information (Q8,9,11,12) each contributed proportionately more (18.2%) to the final eHIE score than the presence of a digital connection and the type and structure of information received (Q7,10) at 13.6%. This asymmetry has the potential to overstate the contribution of volume and breadth of exchange over the connectivity, structure and format of shared information. However the algorithm is applied to all information types once they are identified as applicable to the entity's workflows and thus do not materially alter either eHIE_A or eHIE_B rankings as they apply to all health entities. Weighting of health information exchange components may be desirable, however given the early development stage of this indicator and the higher likelihood that scores may reflect idiosyncratic regional sample characteristics, their absence will not be material until the study is repeated using data from multiple jurisdictions.

The numerators for entity eHIE scores were calculated as described in Table 8 Section 4.5. The descriptive statistics for components of the numerator are included in Appendix J. Section 4.5 previously described how the eHIE denominator may be calculated using either the entirety of electronic information types (eHIE_A), or one reduced by the highest possible scores of information types which are considered by the health entity as not essential to decision-making in their organization (eHIE_B), that is zero scores for information exchange measures the entity deemed "not applicable" are ignored. Histograms of both eHIE_A (Figure 12) and eHIE_B (Figure 13) reveal similarly positively skewed data with the reduction in denominator calculations increasing the mean score of eHIE_B by three percentage points (38.6%) over eHIE_A and the median by two percentage points (20.0 %). Both measures will be included to better understand the impact of expecting all organizations to have the capacity to send and receive any type of clinical information electronically versus allowing each to determine the appropriateness of various types of information to their own workflow.

Notable in both cases is the very high percentage of the population reporting they exchange no clinical information electronically with other health entities. Taking the eHIE_A score as an example, 44% percent of the respondents exchange no information, and 78.1% electronically exchange less than one quarter the total volume of patient health information flowing in and out of the organization. This suggests information systems in the region have very low levels of interoperability and if our hypothesis is correct, correlates with equally low levels of regional system integration.

Figure 12. Frequency and Distribution of eHIE_A

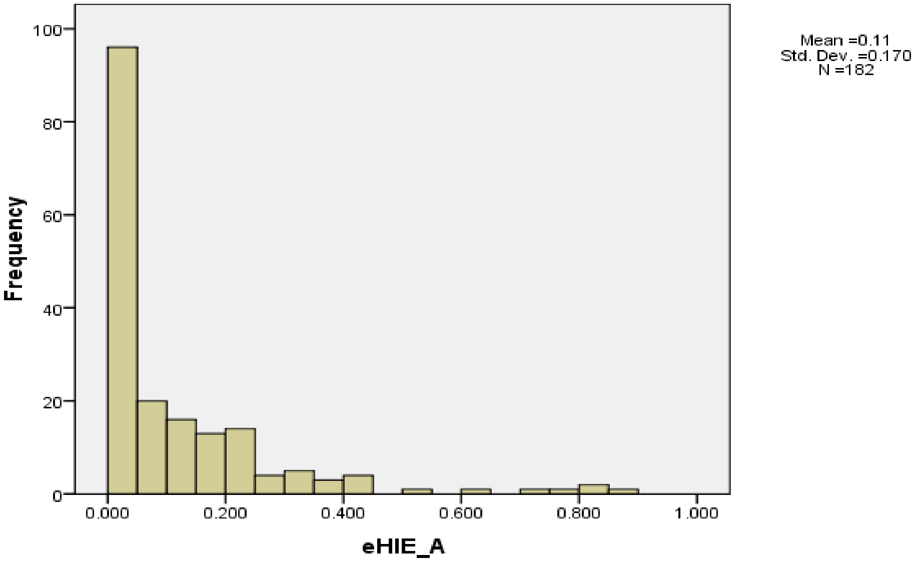
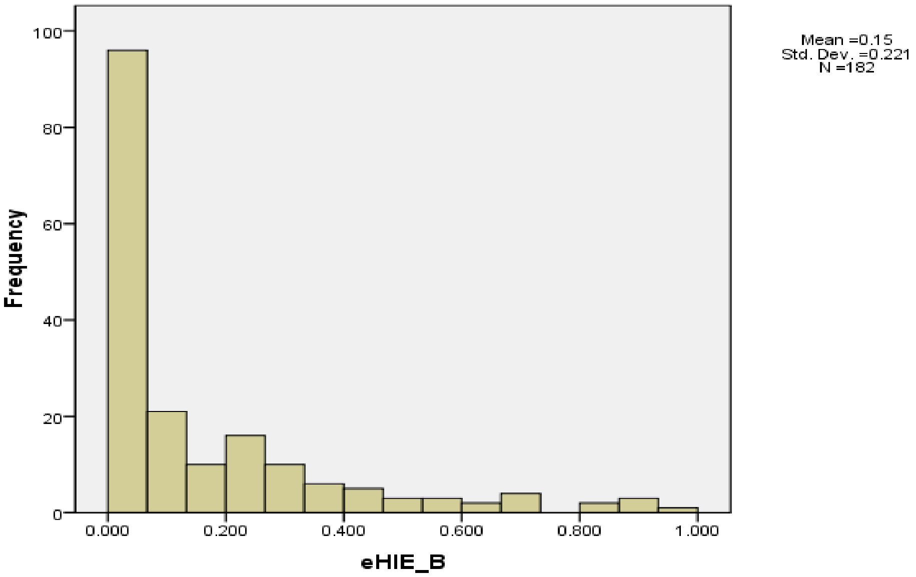


Figure 13. Frequency & Distribution of eHIE_B



It is noteworthy that there is no significant association (χ^2 (1) = 1.859, p <0.173) between whether or not the health entity uses an electronic information system to manage patient clinical information, and high eHIE scores (a binary variable was created from eHIE_B data grouping health entities with scores from 0 to 0.4999 [“low interoperability”] and from 0.5 to 1.0 [“high interoperability”]). However, only three entities without electronic patient information management scored a high eHIE. This is consistent with the literature suggesting that while health entities are increasingly digitizing their records, many retain a paper chart or paper files while sending or receiving health information electronically i.e. accepting batch files of electronic laboratory information via EDI or a portal, but printing hard copies for physician review and storage in a paper health record. There was no significant difference between eHIE scores, rurality and aggregate provider groups or physician specialty.

The following section describes the method used to aggregate the collected data for reporting regional or system eHIE and integration levels.

5.3 System-level eHIE and Integration Indicator Results

5.3.1 Analysis of System-Level eHIE

Both eHIE_B (where the ratio denominator is reduced by those types of information that individual health entities deem “Not Applicable” to their particular practice) and eHIE_A (all types of information included) measures of health system electronic information exchange are reported in weighted and un-weighted formats in Table 15 based on their frequency in the population versus the survey sample. A higher eHIE score approaches 1 (where 100% of all information that could be shared electronically is share electronically with other health entities).

Table 15. Weighted and Un-weighted eHIE Indicator Results by Health Entity Group

Health Entity Group	Freq. in Population (%)	Freq. in Sample (%)	Median		Non-weighted Mean		Weighted by Pop. Mean	
			eHIE_A	eHIE_B	eHIE_A	eHIE_B	eHIE_A	eHIE_B
Hospital	1.5	3.8	0.237	0.237	0.158	0.158	0.063	0.063
CCAC	.2	.5	0.121	0.436	0.121	0.436	0.042	0.153
Primary Care	33.9	30.2	0.056	0.081	0.148	0.167	0.166	0.188
Physician Specialists	32.2	24.2	0	0	0.099	0.108	0.132	0.143
Laboratory	1	2.2	0.119	0.339	0.100	0.352	0.044	0.154
Diagnostic Imaging	1	0.5	0.071	0.116	0.071	0.116	0.124	0.203
Pharmacy	18.9	18.7	0	0	0.055	0.138	0.056	0.139
Public Health	04	1.1	0.046	0.059	0.046	0.059	0.016	0.021
Nursing Home/LTC	6.0	9.3	0.081	0.086	0.081	0.195	0.052	0.125
Comm Health Services	4.0	8.2	0.045	0.063	0.090	0.172	0.044	0.084
Hospice/Pall. Care	0.6	.5	0	0	0	0	0	0
EMS	0.4	.5	0.136	0.245	0.136	0.245	0.095	0.172

The frequency distribution of our survey sample differed from that of the regional population with hospitals, laboratories, nursing homes/long term care, and community health services proportionately over-represented. Technology adoption in certain healthcare sectors may vary depending on the provider, the organization, its facilities and resources, thus a system level indicator based on the mean of a ratio should be adjusted to account for any skewness in the sample distribution from the survey (frequencies of both the population and sample are shown and are included in the algorithm for the eHIE “Weighted by Population” column). Weighting the average eHIE indicators so that each health entity group contributed to the system-level average in a proportion more reflective of the entire system reduced the eHIE_A by 37.1% and the eHIE_B by 21.33%. As health entity groups with higher information exchange activities were over-represented in our sample, a weighted average more appropriately represents the electronic information exchange at the system level.

The system eHIE_A scores range from 0 to .894 and for eHIE_B from 0 to .938. The highest scores emanated from the long term care sector (N=17). All categories of health entity had at least one respondent who reported no electronic information exchange. The system-level weighted average for eHIE_A was 0.07, and for eHIE_B was 0.12. Thus, the most optimistic measure indicates that 12% of clinical information that could be shared was being shared electronically in this region.

In addition to gathering data on the actual incidence of information exchange amongst the regional health entities, data was also collected to determine the participants’ perceptions of integration of and with the regional system. These data points provide a measure of system-level integration against which the eHIE indicator can be compared.

5.3.2 Perceptions of System-Level Integration

Survey respondents were provided with the definition of an integrated healthcare system as described in Section 2.2.1 (p.20). A five point Likert scale was used to measure their perceptions of the integration level in their regional healthcare system /LHIN (Q13), their entity's level of integration with the regional healthcare system/LHIN (Q14), and finally their entity's level of integration with the regional healthcare system/LHIN from the perspective of the amount of information electronically exchanged with other health entities providing care (Q15).

Each of the three questions addressed different constructs focused on the dependent variable of interest, seamless integration. Q13 evaluated the performance of the healthcare system without referencing the responding health entity, Q14 required the respondents to self-evaluate their organization's level of integration with the regional healthcare system and was formulated to provide a constructed measure of system-level integration from an organizational perspective. This variable (Q14) was intended to test the reliability of the eHIE; that is, a high positive correlation is anticipated between, them. Q15 converged respondents' focus on organizations' integration with the system only in the context of the amount of information which was shared electronically with other providers. This variable was derived to determine the strength and direction of integration related to electronic information exchange, and to test the reliability of the integration measure related to the eHIE.

Our theoretical model suggests there should be a positive correlation between levels of interoperability and integration. If perceptions of integration and eHIE are correlated, and there is a correlation between perceptions of integration as measured by Q15 and the system as a whole (Q13), the eHIE can be assumed to be predictive of the level of integration, both as an aggregate indicator of entity's perceptions of integration with the system, and perhaps with the system itself (though the effect size is expected to be small given the large number of factors mediating perceptions of system-level integration). Based on the frequencies, tests for normality were conducted; the Kolmogorov-Smirnoff and Shapiro-Wilks were both highly significant for Q13 *D*(173) = .245, p<.001, Q14 *D*(173) = .233, p<.001, and Q14 *D*(173) = .251, p<.001. Q-Q normality plots were S-shaped, suggesting non-normally distributed data. This was confirmed by skewness statistics of 0.622, 0.724 and 0.948 respectively and called for the use of non-parametric tests.

Table 16. Health Entity's Perceived Levels of Integration (%)

Level of Integration (N=183)	Not at all integrated(1)	Slightly integrated (2)	Moderately integrated (3)	Mostly integrated (4)	Fully integrated (5)
Q13 Regional system integration	30.6	43.3	20.8	4.6	0.6
Q14 Entity's level of system integration	34.1	37.6	19.7	7.5	1.2
Q15 Entity's level of system integration based on electronic information exchange	42.8	36.4	14.5	5.8	0.6

The mean values for integration levels suggest that respondents consider the system to be slightly integrated overall (see Table 17). As expected, anchoring integration to the respondents' level of electronic information exchange in Q15 reduced the respondents' ratings of integration with the system. Furthermore, this question was highly skewed towards 1 (normal distribution is 0) and the lower standard deviation suggests more homogeneity in rankings.

Mean rankings by aggregate groups of providers suggest that, for this sample, there are group differences in perceptions of integration (see Table 18). Not surprisingly hospitals' (mean =2.57) and public health units' (mean = 2.50) perceptions of their integration with the regional system were highest but reported their integration levels as less than "moderately integrated".

Table 17. Levels of System Integration Agreement

Level of Integration	Mean	Median	C.I.	S.D	Skewness
Q13 Regional system integration	2.01	2.00	1.88, 2.14	0.973	0.62
Q14 Entity's level of system integration	2.04	2.00	1.89, 2.19	0.915	0.72
Q15 Entity's level of system integration based on electronic information exchange	1.85	2.00	1.71, 1.99	0.838	0.95

Table 18. Integration Rankings (Q14) by Aggregate Provider Group

Integration rankings	Mean	Median	S.D	Skewness
Hospitals	2.57	3.00	0.54	-0.37
Primary Care	2.17	2.00	1.00	0.74
Physician Specialist	1.98	2.00	1.00	0.70
Laboratory	2.00	2.00	1.00	0
Pharmacy	1.67	1.00	0.89	1.31
Public Health	2.50	2.50	0.71	0
Nursing Home/LTC	2.25	2.00	0.86	0.18
Community Health Services	2.13	2.00	1.19	1.19
EMS	2.04	2.00	0.97	0.72

Relationships between respondents' perceptions of regional system integration (Q13), and their organization's level of integration with it (Q14) ($r_s = .666$, $p<.001$) were highly correlated. Correlations between the regional system integration, the organization's integration and organization's integration based on their level of electronic information exchange were more modestly correlated but still highly statistically significant (Q13 and Q15; $r_s = .397$, $p<.001$, and Q14 and Q15; $r_s = .529$, $p<.001$). These data suggest that each of the constructs are accounting for some common system level integration constructs.

5.4 The Relationship Between Electronic Information Exchange and System Integration

The responses to Q14 selected to examine the relationship between system integration, and Q6 whether or not clinical information is sent and received between different health entities in that system are presented in Table 19. A K-S test confirmed non-parametric data suggesting the use of the Mann-Whitney (U) test statistic.

Significant test statistics for all types of information and sources of exchange consistently reported higher perceptions of integration for those providers who exchanged information electronically over those who did not.

Table 19. Comparison of Perceived Levels of Integration with Types of Information Exchanged (To and From Providers)

Sending patient/client information to:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	137	79%	1.97	2064.5	P<.113
	Yes	36	21%	2.31		
Hospitals	No	149	86%	1.85	1186.0	P<.005**
	Yes	24	14%	2.63		
Laboratories	No	164	95%	2.02	626.5	P<.442
	Yes	9	5%	2.44		
Imaging	No	165	95%	1.99	356.5	P<.021*
	Yes	8	5%	3.00		
Pharmacy	No	165	95%	2.01	475.5	P<.160
	Yes	8	5%	2.63		
CCAC	No	155	90%	1.97	869.5	P<.006**
	Yes	18	10%	2.67		
Public Health	No	167	97%	1.99	195.0	P<.007**
	Yes	6	3%	3.33		
Long Term Care	No	160	92%	1.97	563.0	P<.004**
	Yes	13	8%	2.85		
Other	No	142	82%	2.02	2064.5	P<.569
	Yes	31	18%	2.13		

Receiving patient/client information from:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	145	84%	1.96	1507.0	P<.023*
	Yes	28	16%	2.46		
Hospitals	No	138	80%	1.94	1783.0	P<.012*
	Yes	35	20%	2.43		
Laboratories	No	156	90%	2.01	1075.5	P<.178
	Yes	17	10%	2.35		
Imaging	No	160	92%	1.99	674.5	P<.050*
	Yes	13	8%	2.69		
Pharmacy	No	162	94%	2.00	592.5	P<.035*
	Yes	11	6%	2.64		
CCAC	No	153	88%	1.98	1054.0	P<.017*
	Yes	20	12%	2.50		
Public Health	No	166	96%	2.00	293.5	P<.020*
	Yes	7	4%	3.00		
Long Term Care	No	162	94%	1.99	546.5	P<.024*
	Yes	11	6%	2.73		
Other	No	162	94%	2.02	803.0	P<.564
	Yes	11	6%	2.27		

Sending medication information to:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	151	87%	2.01	1575.5	P<.681
	Yes	22	13%	2.23		
Hospitals	No	160	92%	1.97	616.5	P<.010*
	Yes	13	8%	2.92		
Laboratories	No	170	98%	2.02	156.0	P<.225
	Yes	3	2%	3.00		
Imaging	No	172	99%	2.03	8.0	P<.104
	Yes	1	1%	4.00		
Pharmacy	No	161	93%	2.02	852.0	P<.473
	Yes	12	7%	2.33		
CCAC	No	165	95%	1.99	294.5	P<.005*
	Yes	8	5%	3.13		
Public Health	No	171	99%	2.03	88.0	P<.272
	Yes	2	1%	3.00		
Long Term Care	No	166	96%	2.00	344.5	P<.055*
	Yes	7	4%	3.00		
Other	No	156	90%	2.08	1063.5	P<.158
	Yes	17	10%	1.71		

Receiving medication information from:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	151	87%	1.98	1316.5	P<.098
	Yes	22	13%	2.45		
Hospitals	No	155	90%	1.99	1055.5	P<.075
	Yes	18	10%	2.50		
Laboratories	No	170	98%	2.03	167.0	P<.281
	Yes	3	2%	2.67		
Imaging	No	171	99%	2.04	11.5	P<.429
	Yes	2	1%	2.50		
Pharmacy	No	160	93%	2.00	786.0	P<.123
	Yes	13	1%	2.54		
CCAC	No	160	92%	1.99	623.5	P<.011*
	Yes	13	8%	2.69		
Public Health	No	169	98%	2.02	195.5	P<.129
	Yes	4	2%	2.75		
Long Term Care	No	167	97%	2.01	280.5	P<.054*
	Yes	6	3%	3.00		
Other	No	167	97%	2.04	467.5	P<.769
	Yes	6	3%	2.00		

Sending laboratory information to:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	150	87%	1.97	1300.0	P<.045*
	Yes	23	13%	2.48		
Hospitals	No	159	92%	1.95	523.5	P<.001**
	Yes	14	8%	3.07		
Laboratories	No	166	96%	2.00	332.0	P<.043*
	Yes	7	4%	3.00		
Imaging	No	172	99%	2.03	8.0	P<.104
	Yes	1	1%	4.00		
Pharmacy	No	172	99%	2.03	8.0	P<.104
	Yes	1	1%	4.00		
CCAC	No	168	97%	1.99	119.0	P<.004**
	Yes	5	3%	3.60		
Public Health	No	169	98%	2.01	164.5	P<.065
	Yes	4	2%	3.25		
Long Term Care	No	169	98%	2.01	115.0	P<.018*
	Yes	4	2%	3.53		
Other	No	168	97%	2.03	296.0	P<.236
	Yes	5	3%	2.40		

Receiving laboratory information from:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	157	91%	2.01	1007.0	P<.169
	Yes	16	9%	2.38		
Hospitals	No	144	83%	1.99	1676.5	P<.078
	Yes	29	17%	2.31		
Laboratories	No	134	77%	1.94	1961.0	P<.013*
	Yes	39	23%	2.38		
Imaging	No	170	98%	2.03	167.0	P<.281
	Yes	3	2%	2.67		
Pharmacy	No	172	99%	2.03	8.0	P<.104
	Yes	1	1%	4.00		
CCAC	No	166	96%	2.02	374.0	P<.093
	Yes	7	4%	2.57		
Public Health	No	170	98%	2.02	117.5	P<.092
	Yes	3	2%	3.00		
Long Term Care	No	168	97%	2.02	223.0	P<.060
	Yes	5	3%	2.80		
Other	No	173	100%			
	Yes	0	0%			

Sending diagnostic imaging information to:				Level of perceived integration (N=173)		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	155	90%	1.96	871.0	P<.006**
	Yes	18	10%	2.72		
Hospitals	No	161	93%	1.96	371.5	P<.001**
	Yes	12	7%	3.17		
Laboratories	No	171	99%	2.02	15.0	P<.010*
	Yes	2	1%	4.00		
Imaging	No	168	97%	2.01	204.5	P<.039*
	Yes	5	3%	3.20		
Pharmacy	No	172	99%	2.03	8.0	P<.0104
	Yes	1	1%	4.00		
CCAC	No	168	97%	1.99	69.5	P<.001**
	Yes	5	3%	3.80		
Public Health	No	171	99%	2.03	88.0	P<.272
	Yes	2	1%	3.00		
Long Term Care	No	169	98%	2.00	65.5	P<.004**
	Yes	4	2%	3.75		
Other	No	169	98%	2.03	219.0	P<.205
	Yes	4	2%	2.5		

Receiving diagnosticimaging information from:				Level of perceived integration (N=173)		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	160	92%	2.01	793.5	P<.134
	Yes	13	8%	2.46		
Hospitals	No	145	84%	1.99	1685.0	P<.134
	Yes	28	16%	2.29		
Laboratories	No	167	97%	2.03	410.5	P<.429
	Yes	6	3%	2.33		
Imaging	No	151	87%	1.96	1155.5	P<.015*
	Yes	22	13%	2.59		
Pharmacy	No	172	99%	2.03	8.0	P<.104
	Yes	1	1%	4.00		
CCAC	No	171	99%	2.04	111.5	P<.429
	Yes	2	1%	2.50		
Public Health	No	171	99%	2.04	111.5	P<.429
	Yes	2	1%	2.50		
Long Term Care	No	169	98%	2.01	96.5	P<.010*
	Yes	4	2%	3.25		
Other	No	172	99%	2.04	81.0	P<.948
	Yes	1	1%	2.00		

Sending public health information to:				Level of perceived integration (N=173)		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	166	96%	1.99	270.0	P<.012*
	Yes	7	4%	3.14		
Hospitals	No	170	98%	2.02	68.0	P<.022*
	Yes	3	2%	3.33		
Laboratories	No	172	99%	2.03	8.0	P<.014
	Yes	1	1%	4.00		
Imaging	No	172	99%	2.03	8.0	P<.014
	Yes	1	1%	4.00		
Pharmacy	No	172	99%	2.03	8.0	P<.014
	Yes	1	1%	4.00		
CCAC	No	171	99%	2.02	38.5	P<.054*
	Yes	2	1%	3.50		
Public Health	No	164	95%	1.99	341.5	P<.004**
	Yes	9	5%	3.00		
Long Term Care	No	172	99%	2.03	8.0	P<.014
	Yes	1	1%	4.00		
Other	No	169	98%	2.05	296.0	P<.655
	Yes	4	2%	1.75		

Receiving public health information from:				Level of perceived integration (N=173)		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	167	97%	2.02	337.5	P<.153
	Yes	6	3%	2.67		
Hospitals	No	170	98%	2.02	68.0	P<.022*
	Yes	3	2%	3.33		
Laboratories	No	171	99%	2.02	38.5	P<.054*
	Yes	2	1%	3.50		
Imaging	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Pharmacy	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
CCAC	No	166	96%	2.02	386.5	P<.114
	Yes	7	4%	2.57		
Public Health	No	158	91%	1.98	786.0	P<.023*
	Yes	15	9%	2.67		
Long Term Care	No	170	98%	2.02	68.0	P<.022*
	Yes	3	2%	3.33		
Other	No	171	99%	2.04	161.0	P<.893
	Yes	2	1%	2.00		

Sending referral information to:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	152	87%	1.99	1280.0`	P<.121
	Yes	21	13%	2.43		
Hospitals	No	164	92%	1.99	380.0	P<.010
	Yes	9	8%	3.00		
Laboratories	No	171	96%	2.02	31.0	P<.037*
	Yes	2	4%	4.00		
Imaging	No	171	99%	2.02	31.0	P<.037*
	Yes	2	1%	4.00		
Pharmacy	No	170	99%	2.03	179.5	P<.355
	Yes	3	1%	2.67		
CCAC	No	166	97%	2.02	374.0	P<.093
	Yes	7	3%	2.57		
Public Health	No	172	98%	2.04	81.0	P<.948
	Yes	1	2%	2.00		
Long Term Care	No	170	98%	2.03	167.0	P<.281
	Yes	3	2%	3.53		
Other	No	168	97%	2.03	296.0	P<.236
	Yes	5	3%	2.40		

Receiving referral information from:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	149	86%	1.96	1272.5	P<.017*
	Yes	4	14%	2.54		
Hospitals	No	160	92%	1.99	682.0	P<.030*
	Yes	13	8%	2.62		
Laboratories	No	172	99%	2.02	0.5	P<.012*
	Yes	1	1%	5.00		
Imaging	No	172	99%	2.02	0.5	P<.012*
	Yes	1	1%	5.00		
Pharmacy	No	172	99%	2.03	8.0	P<.104
	Yes	1	1%	4.00		
CCAC	No	160	92%	1.99	636.0	P<.014*
	Yes	13	8%	2.69		
Public Health	No	169	98%	2.02	195.5	P<.129
	Yes	4	2%	2.75		
Long Term Care	No	169	98%	2.02	195.5	P<.129
	Yes	4	2%	2.75		
Other	No	170	98%	2.04	252.5	P<.976
	Yes	3	2%	2.00		

Sending problem list/history information to:				Level of perceived integration (N=173)		
				Median	U	Sig. (2 tail)
Physicians	No	152	88%	2.00	1391.5	P<.316
	Yes	21	12%	2.33		
Hospitals	No	164	95%	1.98	307.0	P<.002**
	Yes	9	5%	3.22		
Laboratories	No	173	100%			
	Yes	0	0%			
Imaging	No	173	100%			
	Yes	0	0%			
Pharmacy	No	171	99%	2.04	150.0	P<.776
	Yes	2	1%	2.50		
CCAC	No	164	95%	199	417.0	P<.021*
	Yes	9	5%	2.89		
Public Health	No	172	99%	2.04	81.0	P<.948
	Yes	1	1%	2.00		
Long Term Care	No	168	97%	2.01	254.0	P<.113
	Yes	5	3%	3.00		
Other	No	166	96%	2.04	571.0	P<.935
	Yes	7	4%	2.00		

Receiving problem list/history information from:				Level of perceived integration (N=173)		
				Median	U	Sig. (2 tail)
Physicians	No	154	89%	1.98	1095.0	P<.060
	Yes	19	11%	2.53		
Hospitals	No	157	91%	1.94	568.5	P<.001**
	Yes	16	9%	3.00		
Laboratories	No	173	100%			
	Yes	0	0%			
Imaging	No	173	100%			
	Yes	0	0%			
Pharmacy	No	171	99%	2.04	150.0	P<.776
	Yes	2	1%	2.50		
CCAC	No	166	96%	2.01	324.5	P<.037*
	Yes	7	4%	2.71		
Public Health	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Long Term Care	No	168	97%	2.02	223.0	P<.060
	Yes	5	3%	2.80		
Other	No	173	100%			
	Yes	0	0%			

Sending scheduling information to:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	169	98%	2.03	257.5	P<.391
	Yes	4	2%	2.50		
Hospitals	No	168	97%	2.00	100.5	P<.002*
	Yes	5	3%	3.40		
Laboratories	No	173	100%			
	Yes	0	0%			
Imaging	No	173	100%			
	Yes	0	0%			
Pharmacy	No	173	100%			
	Yes	0	0%			
CCAC	No	170	98%	2.04	190.5	P<.429
	Yes	3	2%	2.33		
Public Health	No	173	100%			
	Yes	0	0%			
Long Term Care	No	172	99%	2.04	81.0	P<.948
	Yes	1	1%	2.50		
Other	No	167	97%	2.02	361.0	P<.221
	Yes	6	3%	2.50		

Receiving scheduling information from:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	167	97%	2.02	361.0	P<.221
	Yes	6	3%	2.50		
Hospitals	No	166	96$	1.99	202.0	P<.002**
	Yes	7	4%	3.14		
Laboratories	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Imaging	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Pharmacy	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	2.00		
CCAC	No	169	98%	2.03	219.0	P<.205
	Yes	4	2%	2.50		
Public Health	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Long Term Care	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Other	No	171	99%	2.03	88.0	P<.272
	Yes	2	1%	3.00		

Sending inpatient/outpatient treatment information to:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	160	92%	1.99	724.0	P<.055*
	Yes	13	8%	2.62		
Hospitals	No	167	97%	2.01	280.5	P<.054*
	Yes	6	3%	3.00		
Laboratories	No	173	100%			
	Yes	0	0%			
Imaging	No	172	99%	2.02	0.5	P<.012*
	Yes	1	1%	5.00		
Pharmacy	No	171	99%	2.01	7.5	P<.003**
	Yes	2	1%	4.50		
CCAC	No	169	98%	2.01	115.0	P<.018*
	Yes	4	2%	3.50		
Public Health	No	171	99%	2.03	88.0	P<.272
	Yes	2	1%	3.00		
Long Term Care	No	171	99%	2.01	7.5	P<.003*
	Yes	2	1%	4.50		
Other	No	171	99%	2.04	111.5	P<.429
	Yes	2	1%	2.50		

Receiving inpatient/outpatient treatment information from:				**Level of perceived integration (N=173)**		
				Median	**U**	**Sig. (2 tail)**
Physicians	No	158	91%	1.99	843.0	P<.052*
	Yes	15	9%	2.53		
Hospitals	No	148	86%	1.98	1464.5	P<.079
	Yes	25	14%	2.40		
Laboratories	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Imaging	No	172	99%	2.03	31.5	P<.370
	Yes	1	1%	3.00		
Pharmacy	No	171	99%	2.02	38.5	P<.054*
	Yes	2	1%	3.50		
CCAC	No	168	97%	2.02	223.0	P<.060
	Yes	5	3%	2.80		
Public Health	No	171	99%	2.04	111.5	P<.429
	Yes	2	1%	2.50		
Long Term Care	No	169	98%	2.02	195.5	P<.129
	Yes	4	2%	2.75		
Other	No	172	99%	2.04	81.0	P<.948
	Yes	1	1%	2.00		

5.4.1 System-Level Indicators of Integration from Electronic Health Information Exchange Derived by Expert Consensus

The formulae for calculation and results for the three indicators, using data collected from the regional survey as described in Section 4.2, are outlined in Table 20.

Table 20. Expert Consensus Indicators

	Consensus Indicator	%	Calculation
1	Healthcare providers who are sharing health information electronically	61.7	The number of respondents answering "yes" to either sending or receiving any type of electronic information [Q4] divided by the total number of respondents
2	Providers whose patients' demographic information is available electronically	39.6	The number of respondents answering "yes" to sending or receiving patient client information to any type of provider [all Q6a] divided by the total number of respondents
3	Providers capable of sending public health information electronically to Public Health	4.9	The number of respondents answering 'yes' to sending public health information to Public Health [Q6fSN9] divided by the total number of respondents

Results identify Consensus Indicator 1 as a gross measure of those providers who share any electronic information; it provides no information as to how that is achieved, what is being exchanged, to whom, and to what extent. This indicator is clearly not representative of the regional eHIE measure which indicates that only 12% of clinical information is being exchanged and thus was not investigated further. A more detailed analysis of Consensus Indicator 2 and 3 is included below. Indicator 2 represents the number of respondents who are electronically exchanging the most basic patient demographic information and may overstate electronic information exchange generally. Indicator 3 may be the most useful of the three indicators in that it speaks to the respondents' capacity for and willingness to send public health information to Public Health, a critical source of information for syndromic surveillance and decision-making for health policy. Results for both indicators will be discussed.

5.4.2 Patient/Client (Demographics) Information Exchange

Entities sending patient/client information to hospitals (*U=1186.0, p<.005, r = 0.21)*, imaging facilities (*U=365.0, p<.021, r = 0.18),* the community care access centre (*U=869.5.0, p<.006, r = 0.11),* public health (*U=195.0, p<.007, r = 0.20),* and long term care facilities (*U=563.0, p<.004, r = 0.22),* all report higher perceived levels of integration with the healthcare system.

Entities receiving patient/client information from physicians (*U=1507.0, p<.023, r = 0.17),* hospitals (*U=1783.0, p<.012, r = 0.19),* imaging facilities (*U=674.5 p<.050, r = 0.19),* pharmacies (*U=592.5, p<.035, r = 0.15), the community care access centre* (*U=1054.0, p<.017, r = 0.21),* public health (*U=293.5, p<.020, r = 0.18)* and long term care facilities (*U=546.5, p<.024, r = 0.17),* all report higher perceived levels of integration with the healthcare system.

These results confirm that those entities exchanging patient/client information, particularly those who are sending it to hospitals, CCAC's, public health and long term care, show highly significant improvement in their perceptions of integration with the healthcare system

5.4.3 Public Health Information Exchange

Entities sending public health information (such as vaccination information) show statistically significant increases in perceptions of their organization’s integration with the regional health system including: physicians ((*U=270.0, p<.012),* hospitals (*U=68.0, p<.022, r = 0.19),* and public health (*U=341.5, p<.004).*

Entities receiving public health information from hospitals (*U=68.0, p<.022)*, hospitals. laboratories (*U=38.5 p<.054),* public health (*U=786.0, p<.023)* and long term care facilities (*U=68.0, p<.022),* all report higher perceived levels of integration with the healthcare system. It would therefore appear that the percentage of providers capable of sending public health information electronically to the Public Health Unit is a suitable proxy for health entities’ perceptions of integration with the healthcare system at this time.

5.4.4 The Relationship between eHIE and System Integration

Finally, the relationship between integration and eHIE measures was examined using bivariate correlation techniques. Moderate but highly significant correlations were discovered between eHIE_A and integration with the regional system (Q14; r_s = .222, p<.003 and Q15; r_s = .442, p<.001) and eHIE_B and system integration (Q14; r_s = .198, p<.009 and Q15; r_s = .432, p<.001).

Ordinal regression was used to examine the predictive relationship between system-level integration and inter-organizational electronic health information exchange further. First, binning was use to convert eHIE_A and eHIE_B data into five categories to facilitate comparison with the five integration Likert categories. We ran the logit model but found that it was not appropriate as the test of parallelism was not satisfied. Because we are able to say that the likelihood of lower scores is higher for our sample the negative log-log link function was used to describe the data (Norušis, 2011). We focused on Q14 integration as a representative integration outcome measure and found that the overall model fit for both indicators eHIE_A ($\chi^2 = 19.112$, $p<.001$) and eHIE_B ($\chi^2 = 24.05$, $p<.001$) was statistically significant suggesting that both are correlated with system-level integration.

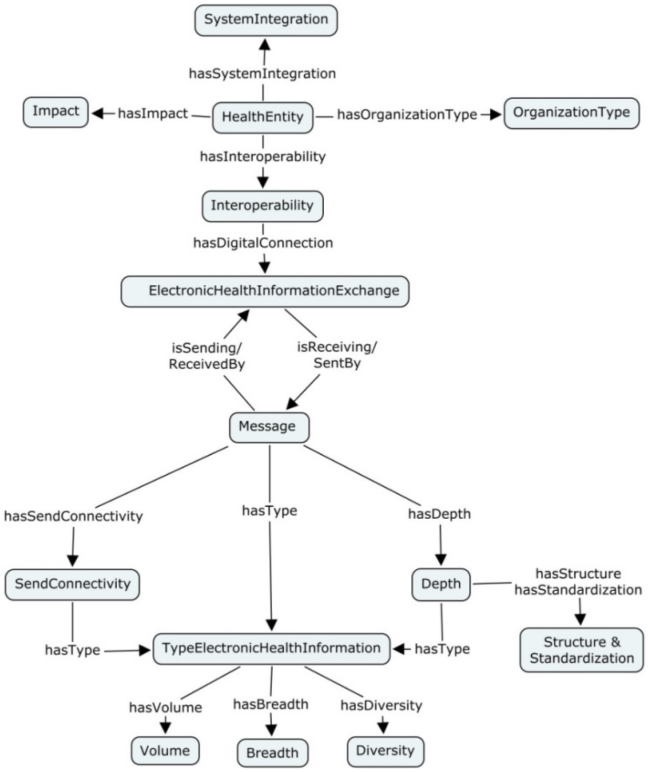
Beyond the statistical testing of our measurement model, we aimed to derive a formal ontology of the measurement model (as depicted in Figure 5). The results are presented in the following section.

5.5 Ontological Modeling of the Domain

Repeated refinements to the ontology were necessary as a result of knowledge gained through iterative discussions with stakeholders in the region during the course of the nominal group process, with survey respondents and ontology experts. The ontology's classes, object properties, and data properties and were refined as data collection proceeded, as well as during analysis. Data collected from each responding health entity in the regional survey described in Section 4.4 populated the ontology. The HermiT® reasoner was used to validate the logic of the interoperability measure, and also facilitate a novel approach to data quality checking and validation using a sample from the Ontario Hospital Association's *Clinical Capabilities and eHealth Adoption: Technologies and Applications Survey 2010.*

The ontology takes the informal conceptualization of our measurement model presented in Figure 5 (reproduced again in Figure 14 below), and “formalizes” the components as outlined in our measurement matrix in (see Table 6, p.104). Relevant literature provided guidance for the ontology classes (for example, (Gruber, 1993; Horridge et al., 2009; Noy & McGuinness, 2000; Rector et al., 2004) and instances (or examples) drawn from the survey data were used to populate the ontology. The focus, as previously noted, is on clinical information which is contained in a health record (Gorman, 1995) and shared electronically with other health entities in the system, and its correlation with levels of system integration.

Figure 14. Conceptual model of electronic health information exchange and related components



The upper level ontology (named Regional Healthcare System Interoperability and Electronic Information Exchange Measurement Ontology, Version 11) is referred to here as HEIO. The value of the ontology to the study was to:

1. Formalize a model for regional electronic healthcare information exchange quantification (measured by the eHIE indicator using collected survey data from participating health entities), and provide a permanent representation of domain concepts in the form of a dictionary of terminology or taxonomy in natural language;
2. Specify the taxonomy for the entities, processes, relations, and properties in the model and ontology to clearly communicate the domain and maximize potential extensibility in future research;
3. Visualize the model;
4. Examine the final component of the model, “impact”; and
5. Demonstrate automatic data quality checking for inconsistency in results using an unrelated existing database of reported hospital clinical technology capabilities, and logic rules and constraints applied to different classes through their properties and relationships with other classes.

5.5.1 The Taxonomy and Relationships

The archetype patterns that occur at a high level of abstraction (Raghupathi & Umar, 2011) and which this ontology models are classes called HealthEntities, and TypeElectronicHealthInformation.[5] Figure 15.illustrates Protégé's customizable application interface showing the collapsed class archetype, with TypeElectronicHealthInformation expanded to display each of the subclasses of information represented in clinical information exchanges, and which were used to gather data in Q 6 – 12 in the regional eHIE survey. The second pane provides a visual representation of the relationship between the two classes using OntoGraf (a Protégé ® add-on to assist with visualizing and navigating the ontology). The final panel depicts properties or rules which are applied to the class (health entity) which includes not only those information exchange properties related to measuring information exchange but also the properties used to perform data quality checks and validation (such as _Appl_hasOversight which will be expanded on and reported in Section 5.6.1).

Relationships isSending, isReceiving, isSentBy, and isReceivedBy are represented by coloured directional lines between the two superclasses in the second panel and are interpreted in natural language as: a health entity, as described in the model, sends and receives certain types of electronic health information, and electronic health information is sent and received by individual health entities.

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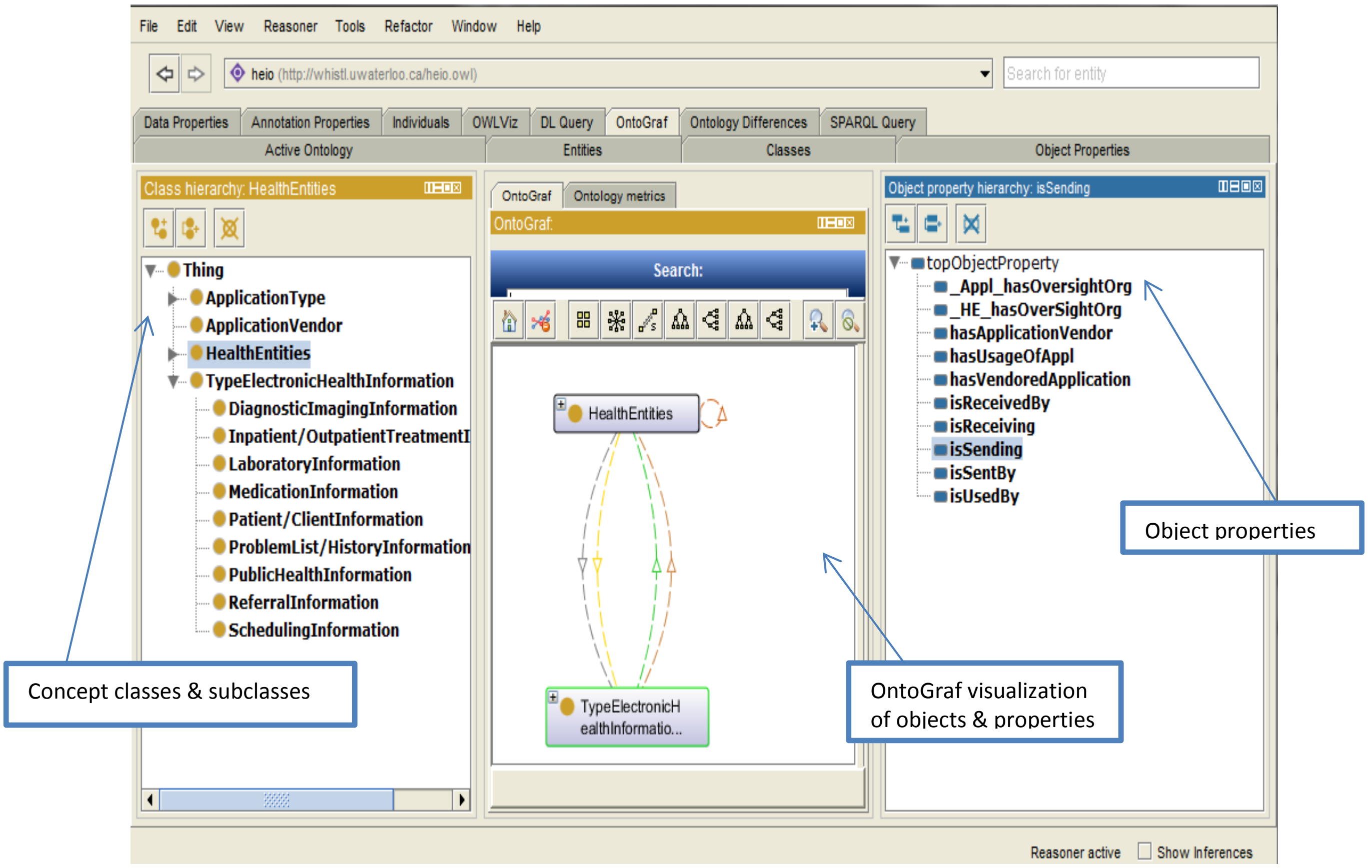
[5] Other ApplicationType and ApplicationVendor are classes created for the secondary purpose of data quality checking and are addressed in 5.6.1.

Figure 15. Upper Level Classes for Regional Clinical Information Exchange Model



Concept classes & subclasses

OntoGraf visualization of objects & properties

Object properties

All classes group together conceptually similar people, things or concepts i.e. physicians, clinical applications or low interoperability entities. The ontology outlines an explicit set of axioms or logical assertions about the classes (and subclasses) to determine the membership of the class; all subclasses inherit the properties of higher level classes. Instances that populate the class satisfy the axioms or logical conditions of the class and become members of those classes (an individual can be a member of none or more than one class). So for instance, the upper level class HealthEntities contains individuals that satisfy the natural language axiom:

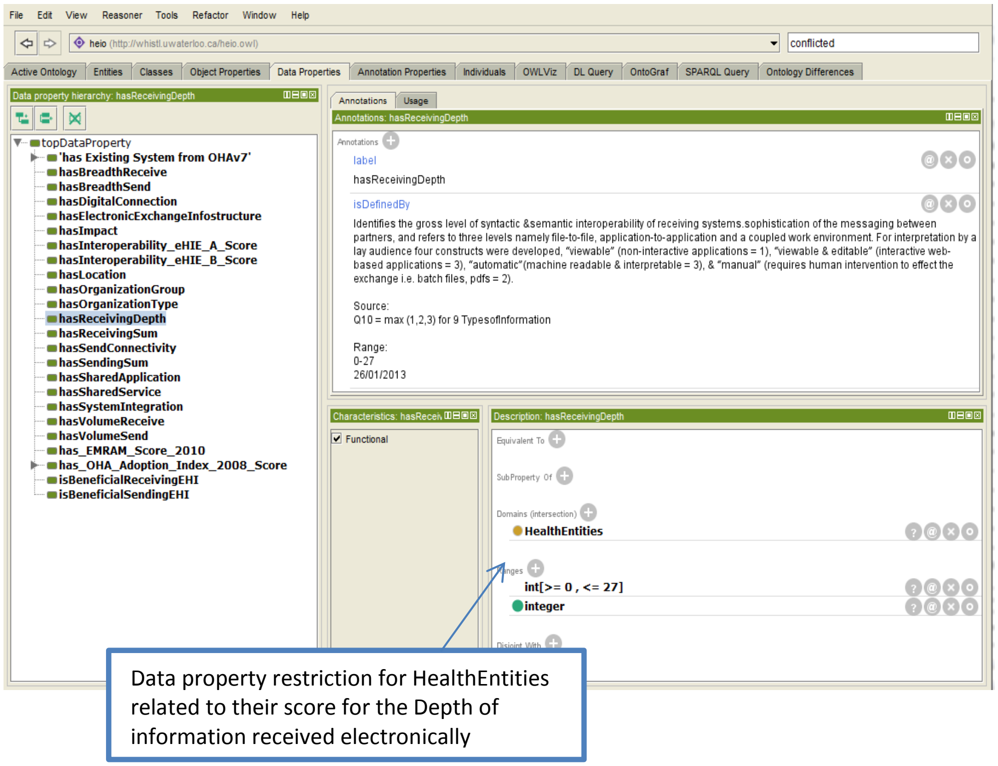
“A Health Entity is any health care service provider or organization, governed by a single corporate body and delivering clinical care in one or more locations under one or more corporate names, to individual patients or groups of patients, and where the predominant funding is from public sources. In relation to ElectronicHealthInformation the entity may be represented by a server, URI or URL associated with a healthcare service provider or organization which may or may not be within the "scope" i.e. within the geographic boundaries of the [LHIN name withheld]. An entity must deliver care from one or more geographic location within the healthcare system, but the corporate head office may be from outside the boundaries of the healthcare system.” (See HEIO V 1.11 Class hierarchy: HealthEntities, Annotations).

Logically, the constraints on the HealthEntities superclass for this ontology were defined as entries in a column in an excel spreadsheet listing all those health entities which responded to the eHIE survey, and identified themselves as a particular organization type. As explained previously, a more comprehensive data collection tool could automatically classify respondents (and check for anomalies) based on rules, for example by equivalence of name or number of beds.

Features or attributes of the concepts are controlled by assigning properties or restrictions to the class. There are two types of properties: object properties describe binary relationships that link classes together, and data properties describe binary relations that link classes to types of data. Data types have an arity of one, that is, they have only one function, and constraints monitor the type and range of data that can be accepted i.e. integer, date, or string, and range restrictions such as integer must be between 60 and 136.

These explicit relationships are the same relationships represented in the informal ontology (see Figure 6) and in the eHIE Scoring Rubric in Table 8. Figure 16 highlights the data property hasReceivingDepth (which correlates with the Depth construct in our informal model), the natural language narrative regarding its definition, data source and ranges, as well as the logical restrictions placed on the property, that it applies to the class of all HealthEntities, and that the range of reasonableness is an integer that is greater than or equal to 0 or less than or equal to 27.

Figure 16. Protégé® Data Property, Annotation and Description Panes



label
hasReceivingDepth

isDefinedBy
Identifies the gross level of syntactic &semantic interoperability of receiving systems.sophistication of the messaging between partners, and refers to three levels namely file-to-file, application-to-application and a coupled work environment. For interpretation by a lay audience four constructs were developed, "viewable" (non-interactive applications = 1), "viewable & editable" (interactive web-based applications = 3), "automatic"(machine readable & interpretable = 3), & "manual" (requires human intervention to effect the exchange i.e. batch files, pdfs = 2).

Source:
Q10 = max (1,2,3) for 9 TypesofInformation

Range:
0-27
26/01/2013

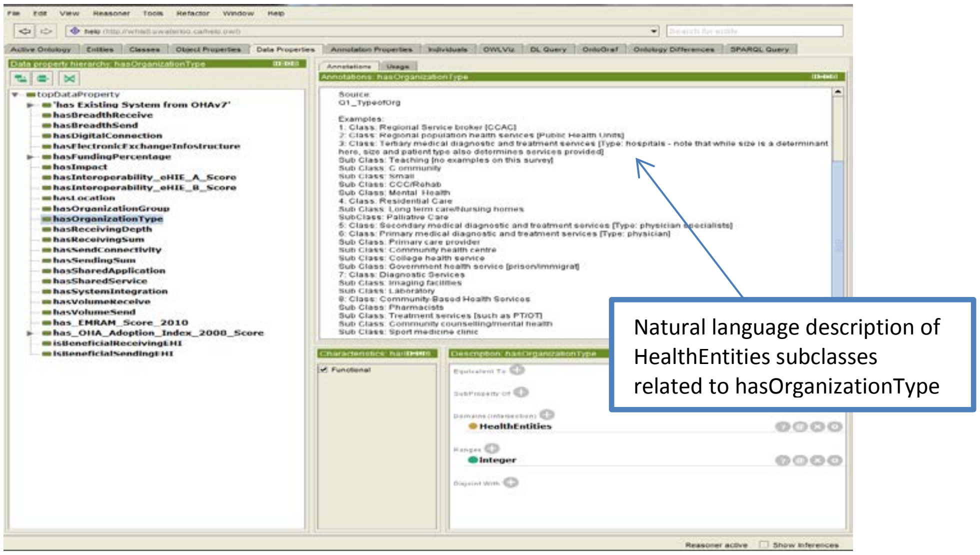
Domains (intersection)
HealthEntities

Ranges
int[>= 0 , <= 27]
integer

Data property restriction for HealthEntities related to their score for the Depth of information received electronically

HealthEntities subclasses were created according to the type of providers delivering care in the region and which require clinical information for decision-making. The HealthEntities each have an object property, amongst others, called typeOfOrganization that links individuals whose characteristics or properties facilitate their organization into logical subclasses which are more specific (such as family health teams or pharmacies) (see Figure 17 and Appendix I).

Figure 17. Protégé® Object Property, Annotation and Description Panes



Source:
Q1_TypeofOrg

Examples:
1: Class: Regional Service broker [CCAC]
2: Class: Regional population health services [Public Health Units]
3: Class: Tertiary medical diagnostic and treatment services [Type: hospitals - note that while size is a determinant here, size and patient type also determines services provided]
Sub Class: Teaching [no examples on this survey]
Sub Class: C ommunity
Sub Class: Small
Sub Class: CCC/Rehab
Sub Class: Mental Health
4: Class: Residential Care
Sub Class: Long term care/Nursing homes
SubClass: Palliative Care
5: Class: Secondary medical diagnostic and treatment services [Type: physician specialists]
6: Class: Primary medical diagnostic and treatment services [Type: physician]
Sub Class: Primary care provider
Sub Class: Community health centre
Sub Class: College health service
Sub Class: Government health service [prison/immigrat]
7: Class: Diagnostic Services
Sub Class: Imaging facilities
Sub Class: Laboratory
8: Class: Community-Based Health Services
Sub Class: Pharmacists
Sub Class: Treatment services [such as PT/OT]
Sub Class: Community counselling/mental health
Sub Class: Sport medicine clinic

☑ Functional

Natural language description of HealthEntities subclasses related to hasOrganizationType

These subclasses are understood to have meaningful differences in adoption of health information technology and capacity for electronic information exchange (for example, Decker, Jamoom, & Sisk, 2012). Annotated metadata or natural language notes create a dictionary of terms for each labeled class, data and object property, and individual (no individual annotations are available in this ontology for reasons of participant confidentiality). These notes allow for detailed specification of terms, sources of data, synonyms, specification of data sources, and other information which ensures a complete and accurate knowledge base of the domain. This feature is crucial to shared understanding of the ontology and domain, and necessary to optimize the extensibility of any ontology (see Figure 17).

This ontology successfully visualizes the domain of interest, but more importantly, explicitly specifies the source data and properties to allow for more efficient and accurate application of rules and restrictions for new instances, identification of logical inconsistencies, and can be extended for use with other ontologies as they are developed. This efficiency makes the task of developing comprehensive and linked ontologies of this domain less onerous. Moreover it will allow others to further develop this particular model and ontology to a higher state of representation as knowledge in the domain expands. The ontology's functionality for data validation is demonstrated in Section 5.6.1.

5.5.2 Concept and Relationship Visualization

All data from the survey were loaded into the ontology mapped according to Table 21. All data loaded correctly.

Protégé is a powerful ontology application however it is only able to represent classes such as Hospitals within which instances such as "Cedars Sinai" are categorized; individual instances' properties are inferred from their class associations (determined by their data and object property rules). As a result, in order to examine measurement outcomes from the eHIE survey results (notably outcomes that measured different constructs from the literature, such as depth and breadth, or instances of high or low interoperability derived for the purposes of this study) new classes had to be created. Table 22 contains the classes, subclasses, their axioms and constraints. Constraints are flexible and determined by the goals of the ontology or perspective of those developing it. For instance, the HighIntegration (#3) constraint was set at the middle (>3) of the 1-5 survey Likert scale, similarly HighInteroperability (#4) constraint was set at >.05. Whereas others used constraints that reflected relative measures, such as HighReceivingSum which was set at <=11 (out of a possible score of 98) as this represented the median score for respondents on the survey**.**

Table 21. Mapping of Ontology, Conceptual Model & Survey

Ontology Construct	Survey Question No.	Conceptual Model Figure 5	Imputed
HealthEntities	1	HealthEntities	
hasOrganizationGroup	1	HealthEntities	
hasOrganizationType	1	HealthEntities	
hasLocation			External database
hasSystemIntegration	14	SystemIntegration	
hasImpact	16,17	Impact	
hasDigitalConnection	4	hasDigitalConnection	Survey eHIE score>0
hasElectronicExchangeInfostructure		Infostructure	Survey Q4
TypeElectronicHealthInformation	6,7,8,9,10, 11,12	TypeElectronicHealth Information & Diversity	
hasSendConnectivity	7	SendConnectivity	
hasReceivingDepth	10	Depth, Structure&Standardization	
hasVolumeReceive	11	Volume	
hasVolumeSend	8	Volume	
hasBreadthReceive	12	Breadth	
hasBreadthSend	9	Breadth	
hasReceivingSum	10,11,12		Survey Score
hasSendingSum	7,8,9		Survey Score
hasInteroperability_eHIE_A_Score	7,8,9,10,11, 12		Survey Score
hasInteroperability_eHIE_B_Score	6,7,8,9,10, 11,12		Survey Score

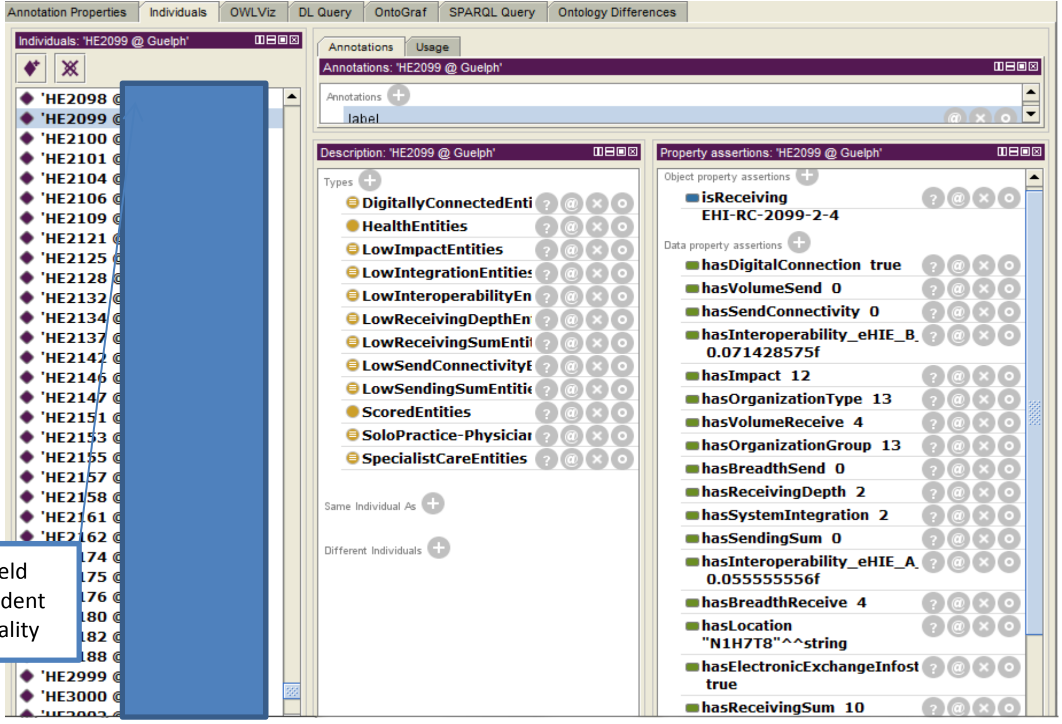
Table 22. ScoredEntities Subclasses & Constraints

Subclass of ScoredEntities & Survey Source	Constraints	Range
1. DigitallyConnectedEntities[Q4]	HealthEntities and (hasDigitalConnection value true)	True,False
2. HighImpactEntities [Q16,17]	HealthEntities and (hasImpact some integer[> 13])	2-23
3. HighIntegrationEntities[Q14]	HealthEntities and (hasSystemIntegration some integer[> 3])	1-5
4. HighInteroperabilityEntities[Q7-12]	HealthEntities and (hasInteroperability_eHIE_B_Score some float[> 0.5f])	0-1[Ratio]
5. HighReceivingDepthEntities[Q10]	HealthEntities and (hasReceivingDepth some integer[> 8])	0-27
6. HighReceivingSumEntities[Q10-12]	HealthEntities and (hasReceivingSum some integer[> 11])	0-98
7. HighSendConnectivityEntities[Q7]	HealthEntities and (hasSendConnectivity some integer[> 8])	0-27
8. HighSendingSumEntities[Q7-9]	HealthEntities and (hasSendingSum some integer[> 9])	0-98
9. LowImpactEntities[Q16,17]	HealthEntities and (hasImpact some integer[<= 13])	2-23
10. LowInteroperabilityEntities[Q7-12]	HealthEntities and (hasInteroperability_eHIE_B_Score some float[<= 0.5f])	0-1
11. LowIntegrationEntities[Q14]	HealthEntities and (hasSystemIntegration some integer[<=3])	1-5
12. LowReceivingDepthEntities[Q10]	HealthEntities and (hasReceivingDepth some integer[<= 8])	0-27
13. LowReceivingSumEntities[Q10-12]	HealthEntities and (hasReceivingSum some integer[<= 11])	0-98
14. LowSendConnectivityEntities[Q7]	HealthEntities and (hasSendConnectivity some integer[<= 8])	0-27
15. LowSendingSumEntities[Q7-9]	HealthEntities and (hasSendingSum some integer[<= 9])	0-98

HealthEntities' data are displayed in the Individual's pane, along with the values associated with the data property assertions (see Figure 18). Here we are able to determine that HealthEntity2099 is a specialist physician in a solo practice (OrganizationType 13) operating out of [city withheld] who is exchanging clinical health information outside their organization. They are not sending any clinical information (SendConnectivity=0, VolumeSend=0) but they are receiving information that is viewable and editable online (has ReceivingDepth=2). Of all the nine types of clinical information investigated by this ontology and which the entity believes is applicable to their practice, the practice is sharing 7.14% of it electronically (hasInteroperability_eHIEB_0.07142). From their responses to the survey the ontology has automatically made HE2099 a member of a number of classes such as DigitallyConnectedEntities (has an internet connection), LowInteroperabilityEntities (eHIE_B less than or equal to 0.5), LowIntegrationEntities (rates their integration as less than or equal to 3).

The HermiT reasoner was used throughout the process of development to infer relationships based on the restrictions and rules placed on classes and data, and to identify logical inconsistencies in axioms in an ontology. Individuals were classified into the ScoredEntities classes based on their Property assertions.

Figure 18. Individual's Pane and DataProperty Assertions



Individuals: 'HE2099 @ Guelph'

'HE2098 @ [redacted]
'HE2099 @
'HE2100 @
'HE2101 @
'HE2104 @
'HE2106 @
'HE2109 @
'HE2121 @
'HE2125 @
'HE2128 @
'HE2132 @
'HE2134 @
'HE2137 @
'HE2142 @
'HE2146 @
'HE2147 @
'HE2151 @
'HE2153 @
'HE2155 @
'HE2157 @
'HE2158 @
'HE2161 @
'HE2162 @
174 @
175 @
176 @
180 @
182 @
188 @
'HE2999 @
'HE3000 @

Annotations: 'HE2099 @ Guelph'

Description: 'HE2099 @ Guelph'

Types
- DigitallyConnectedEnti
- HealthEntities
- LowImpactEntities
- LowIntegrationEntities
- LowInteroperabilityEn
- LowReceivingDepthEn
- LowReceivingSumEntit
- LowSendConnectivityE
- LowSendingSumEntitie
- ScoredEntities
- SoloPractice-Physiciar
- SpecialistCareEntities

Property assertions: 'HE2099 @ Guelph'

Object property assertions
- isReceiving EHI-RC-2099-2-4

Data property assertions
- hasDigitalConnection true
- hasVolumeSend 0
- hasSendConnectivity 0
- hasInteroperability_eHIE_B_ 0.071428575f
- hasImpact 12
- hasOrganizationType 13
- hasVolumeReceive 4
- hasOrganizationGroup 13
- hasBreadthSend 0
- hasReceivingDepth 2
- hasSystemIntegration 2
- hasSendingSum 0
- hasInteroperability_eHIE_A_ 0.055555556f
- hasBreadthReceive 4
- hasLocation "N1H7T8"^^string
- hasElectronicExchangeInfost true
- hasReceivingSum 10

City withheld
for respondent
confidentiality

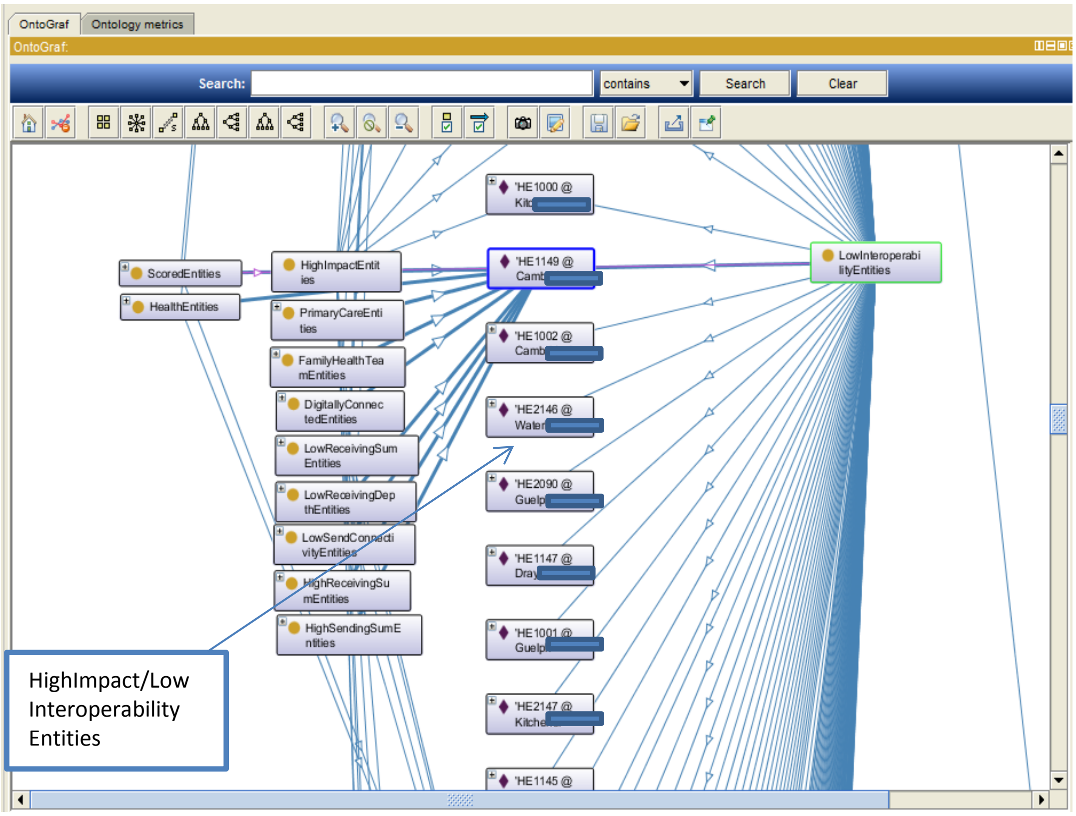
Beyond automatic classification of new classes, properties and instances, the ontology has a number of applications which help to understand and better visualize relationships between concepts in our model:

1. Supporting the visualization of interoperability characteristics or measures for regional analysis and planning purposes.

   Example

   HealthEntities self-reported their Impact. This is a summative measure of the total number of patients or clients in the region that an organization serves in a year, and the total number of health service providers or organizations with whom it exchanges clinical information in support of clinical decision-making, diagnosis or treatment, in any format (by mail, phone, fax and electronically) in a year. Much health information system investment has been focused on the hospital sector. Identifying non-hospital healthcare providers with a high Impact score but low Interoperability score would assist planners and policy-makers to identify individuals or classes with a higher potential for impact based on the number of clients or information exchange partners who would be affected by increased investment. Figure 19 demonstrates a method of examining such an opportunity.

Figure 19. Expanded Classification of HighImpact but Low Interoperability HealthEntities

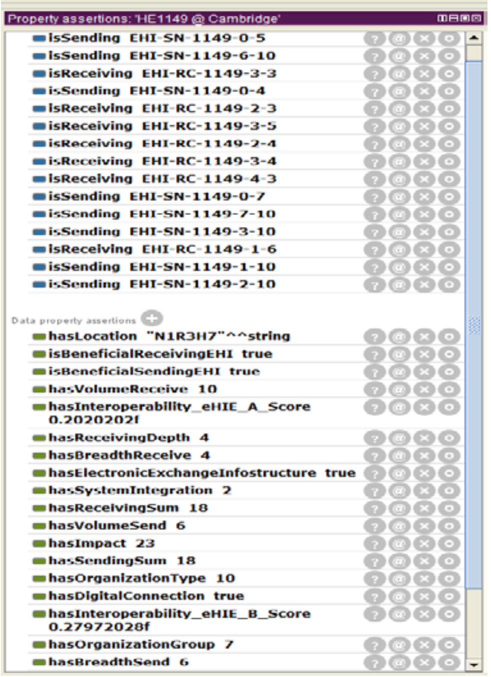


HighImpact/Low Interoperability Entities

OntoGraf was used to visualize HighImpactEntities and LowInteroperabilityEntities and their class relationships; they were both expanded to include their instances. Individuals identified as being a member of both subclasses were immediately visible; further expanding the individual, in this case HE1149, the OntoGraf image reveals that the individual is a member of the Primary Care group, is a Family Health Team, and is exchanging information electronically. But while HE1149 is both sending and receiving information, clearly the breadth and volume is small for the entity to be classed as LowInteroperability.

Examination of the HealthEntity's property assertions (Figure 20) reveals a family health team which is sending: electronic patient/client information to imaging facilities, laboratories, and the CCAC; patient/client information, laboratory and medication information, referral information, problem lists/histories and images to specialists. HE1149 is receiving imaging, laboratory and inpatient/outpatient treatment information from hospitals, imaging information from imaging facilities, laboratory and imaging information from the lab, and mediation information from pharmacies. It ranks itself as being only slightly integrated with the regional healthcare system.

Figure 20. HE1149 Property Assertions



isSending EHI-SN-1149-0-5
isSending EHI-SN-1149-6-10
isReceiving EHI-RC-1149-3-3
isSending EHI-SN-1149-0-4
isReceiving EHI-RC-1149-2-3
isReceiving EHI-RC-1149-3-5
isReceiving EHI-RC-1149-2-4
isReceiving EHI-RC-1149-3-4
isReceiving EHI-RC-1149-4-3
isSending EHI-SN-1149-0-7
isSending EHI-SN-1149-7-10
isSending EHI-SN-1149-3-10
isReceiving EHI-RC-1149-1-6
isSending EHI-SN-1149-1-10
isSending EHI-SN-1149-2-10

Data property assertions

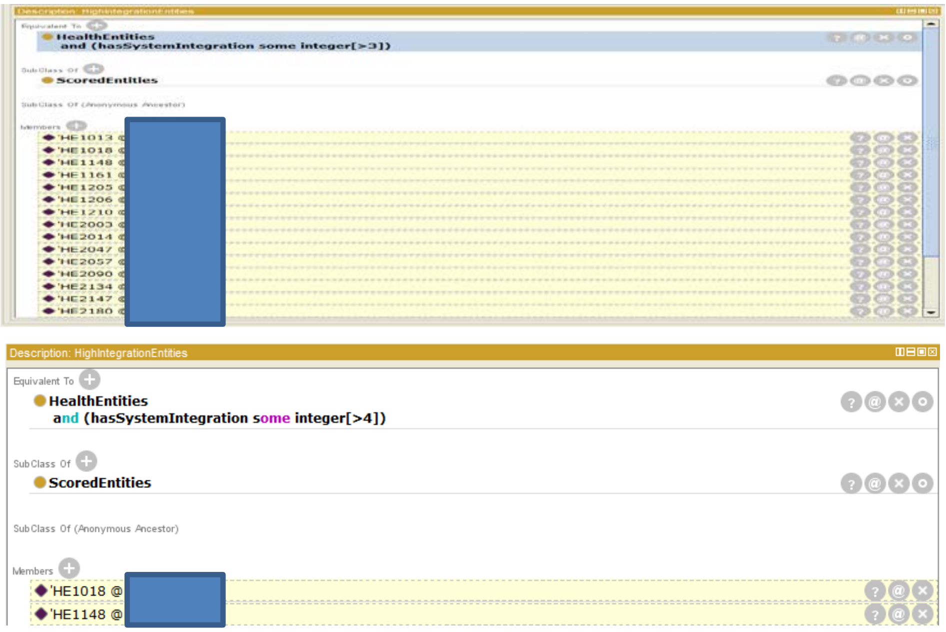
hasLocation "N1R3H7"^^string
isBeneficialReceivingEHI true
isBeneficialSendingEHI true
hasVolumeReceive 10
hasInteroperability_eHIE_A_Score 0.2020202f
hasReceivingDepth 4
hasBreadthReceive 4
hasElectronicExchangeInfostructure true
hasSystemIntegration 2
hasReceivingSum 18
hasVolumeSend 6
hasImpact 23
hasSendingSum 18
hasOrganizationType 10
hasDigitalConnection true
hasInteroperability_eHIE_B_Score 0.27972028f
hasOrganizationGroup 7
hasBreadthSend 6

2. The reasoning and inferencing tool may be used to build a narrative regarding the HealthEntity to examine its relationship between interoperability and system integration, and infer new knowledge.

   <u>Example</u>

   Changing constraints on ScoredEntities classes permits closer examination of outliers and anomalies. Figure 21 demonstrates the results of editing the hasSystemIntegration property constraint from HealthEntities and (hasSystemIntegration some integer[>3]) to HealthEntities and (hasSystemIntegration some integer[>4]) reducing the class members from 15 to 2.

Figure 21. Changing Data Property Constraints for hasSystemIntegration



Description: HighIntegrationEntities

Equivalent To
HealthEntities
and (hasSystemIntegration some integer[>3])

SubClass Of
ScoredEntities

SubClass Of (Anonymous Ancestor)

Members
'HE1013 @
'HE1018 @
'HE1148 @
'HE1161 @
'HE1205 @
'HE1206 @
'HE1210 @
'HE2003 @
'HE2014 @
'HE2047 @
'HE2057 @
'HE2090 @
'HE2134 @
'HE2147 @
'HE2180 @
[redacted]

Description: HighIntegrationEntities

Equivalent To
HealthEntities
and (hasSystemIntegration some integer[>4])

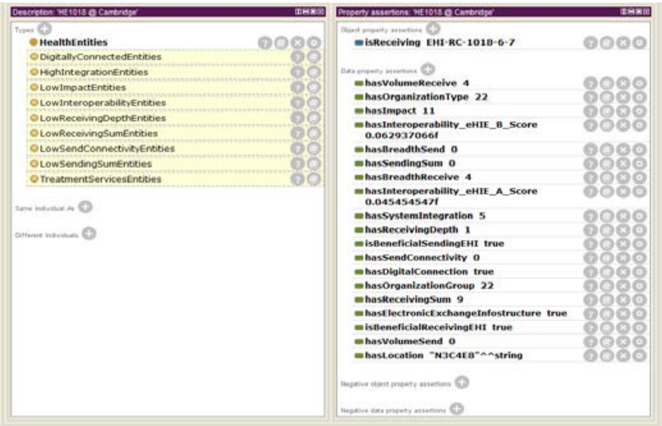
SubClass Of
ScoredEntities

SubClass Of (Anonymous Ancestor)

Members
'HE1018 @
'HE1148 @
[redacted]

Closer examination of the two instances in the newly configured HighSystemEntities class reveals two entities with highly disparate asserted data properties and inferred classifications. HE1148 is a family health team with an eHIE_B of 0.892 suggesting that, accounting for information types which are not applicable to this particular provider, 89.2% of clinical information which is exchanged in any format, is being exchanged electronically. The organization value for hasReceivingSum is 72 out of a possible 98 points yet registers low support for the beneficence of received clinical information. HE1018 (see Figure 22), also provides a profile which warrants further examination. The provider is a member of CommunityBasedHealthServices class and the subclass TreatmentServicesEntities.

Figure 22. Asserted Properties and Inferred Description of HE1018



Description: 'HE1018 @ Cambridge'

Types
- HealthEntities
- DigitallyConnectedEntities
- HighIntegrationEntities
- LowImpactEntities
- LowInteroperabilityEntities
- LowReceivingDepthEntities
- LowReceivingSumEntities
- LowSendConnectivityEntities
- LowSendingSumEntities
- TreatmentServicesEntities

Same Individual As

Different Individuals

Property assertions: 'HE1018 @ Cambridge'

Object property assertions
- isReceiving EHI-RC-1018-6-7

Data property assertions
- hasVolumeReceive 4
- hasOrganizationType 22
- hasImpact 11
- hasInteroperability_eHIE_B_Score 0.062937066f
- hasBreadthSend 0
- hasSendingSum 0
- hasBreadthReceive 4
- hasInteroperability_eHIE_A_Score 0.045454547f
- hasSystemIntegration 5
- hasReceivingDepth 1
- isBeneficialSendingEHI true
- hasSendConnectivity 0
- hasDigitalConnection true
- hasOrganizationGroup 22
- hasReceivingSum 9
- hasElectronicExchangeInfostructure true
- isBeneficialReceivingEHI true
- hasVolumeSend 0
- hasLocation "N3C4E8"^^string

Negative object property assertions

Negative data property assertions

These HealthEntities, generally working through the CCAC, provide care in the community and sometimes in clients' homes. The provider is exchanging electronic information however this does not include sending information to other HealthEntities, merely receiving viewable information online with no capacity for editing or contributing to that online information artifact. This is consistent with the profile of organizations performing in-home services on contract with the CCAC, from whom they receive case profiles electronically.

Of particular interest is the data suggesting that the HealthEntity believes that it is beneficial to both send and receive information electronically, despite their classification by inference in LowInteroperabilityEntities. Furthermore, the lack of electronic information exchange does not impact on their belief that their organization is "mostly integrated" with the regional healthcare system. This result warrants examination in future studies to identify unique factors contributing to the higher than average perceptions of integration. Moreover, explanation of the discrepancy between the low level of interoperability and apparent beneficent attitudes towards electronic information exchange are insufficiently explained by this study and might also be explored

5.6 Logical Testing & Data Validation

According to Walker et al.'s study (as cited in Loreti, Tse, & Murray, 2007) validity has numerous dimensions related to convergence of expert opinion, content, criterion and construct in survey research. For this research study a consensus development process was used to both develop system-level health information exchange indicators that are consistent with health system integration, but also to provide feedback on the framework and feasibility of the data collection instrument. The literature review and consensus development process provided expert input that contributed to the content validity of the survey.

Survey responses were individually monitored for outliers and inconsistencies, and where rules of reasonableness were breeched the respondents were contacted by phone to confirm the accuracy of the submission. In addition, eHIE scores were subject to random manual checks between original survey data and examination of ontology classes to ensure a high level of reliability. Final scores were not confirmed with respondents as data quality or missing responses were addressed at the time of submission.

5.6.1 Logical Testing and Data Validation of eHIE Constructs

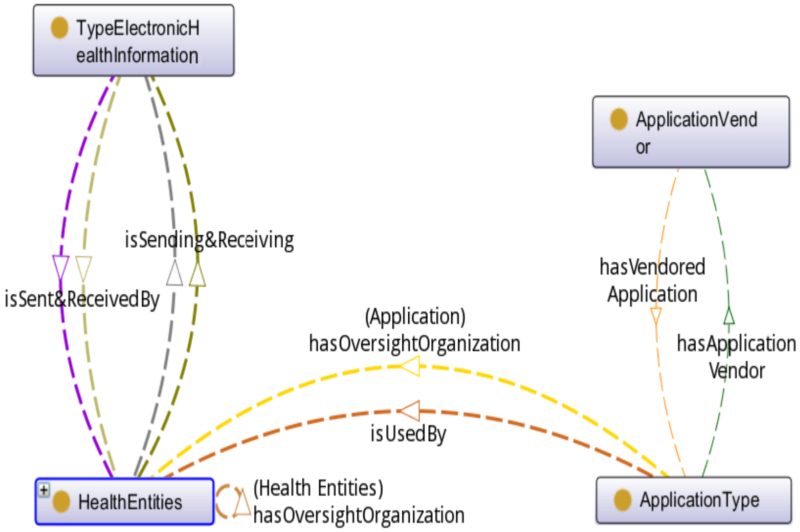
Much of the information that is required to validate organizational and system level information exchange is maintained in proprietary databases in the healthcare sector, for instance each

HealthEntity will have a network log that identifies data inflows and outflows. Alternately it is rarely managed or quantified, as is the case with most HealthEntities using paper-based information exchange systems. Where institutions are publicly funded to deliver care there are expectations of performance accountability, however information is rarely released with individual or organizational identifiers that would allow researchers to validate responses. The exception is the acute care sector, which receives the highest proportion of total health disbursements in Canada (29.1%) (Canadian Institute for Health Information, 2012), and Ontario (38%) (Canadian Institute for Health Information, 2013), and for which there are numerous published indicators on organization websites such as the Ontario Hospital Association and the Canadian Institute for Health Information.

Other publicly funded sectors such as primary care are in nascent stages of developing publicly reported performance measures to improve quality of care; none report at an organization or provider level (Hogg & Dyke, 2011). For this reason, as outlined in the data validation section (Section 5.6), the sample for testing has been restricted to HospitalEntities where there is a history of system-level measurement of constructs related to technology and health information exchange, and development of measurement indicators and published data.

To facilitate logical testing and data validation of technology concepts an independent but complementary database was sought. The Ontario Health Association's *Clinical Capabilities and eHealth Adoption: Technologies and Applications Survey (2010)* provided a dataset of self-reported information from 427 Ontario hospitals, including all seven participating in this study, and which hospitals report using them. A complete list of the 63 applications for which data were collected is included in Appendix K. In addition, the database lists vendors, and hospitals providing shared oversight for common applications. A representation of the data relationships between classes of objects in the OHA database as they are accounted for in the HEIO ontology, ApplicationVendor and ApplicationType, and the superclasses in the HEIO ontology is provided in Figure 23.

Figure 23. Relationships Between OHA Data Objects and HEIO Ontology Superclasses



In order to examine the quality of self-reported data provided by the hospital respondents in the survey a subclass of HealthEntities labeled ConflictedHealthEntities was created. The syntax, and natural language description for the eight subclasses of ConflictedHealthEntities subclasses are outlined in Table 23. Data from the seven hospitals were imported from the OHA database.

Table 23.ConflictedHealthEntities Class Relationships & Constraints

ConflictedHealthEntities Classes &Constraints

Label 1: *Sharing_Any_info_without_Interface_Engines_or_Browser*

Constraint: Hospital cannot report exchanging any information electronically without the reported presence of an existing interface engine or browser application

Syntax: HealthEntities
and (('has existing Browser' value false)
and ('has existing Interface Engines' value false))
and ((isSending some TypeElectronicHealthInformation)
or (isReceiving some TypeElectronicHealthInformation))

Label 2: *Sharing_DI_info_without_DI_system*

Constraint: Hospital cannot report exchanging diagnostic imaging information without an existing DI/PACS system

Syntax: HealthEntities
and (('has existing DI/PACS Data Repository' value false)
and ('has existing Diagnostic Imaging (DI) System' value false))
and ((isSending some DiagnosticImagingInformation)
or (isReceiving some DiagnosticImagingInformation))

Label 3: *Sharing_History_info_without_Client_Registry*

Constraint: Hospital cannot report exchanging patient inpatient/outpatient treatment information without an existing client registry application

Syntax: HealthEntities
and ((isSending some ProblemList/HistoryInformation)
or (isReceiving some ProblemList/HistoryInformation))
and ('has existing Client Registry' value false)

ConflictedHealthEntities Classes &Constraints

Label 4: *Sharing_Lab_info_without_Laboratory_Info_System*

Constraint: Hospital cannot report exchanging laboratory information without an existing laboratory information system application

Syntax:
HealthEntities
and ((isSending some LaboratoryInformation)
or (isReceiving some LaboratoryInformation))
and ('has existing Laboratory Information System' value false)

Label 5: *Sharing_Med_info_without_Drug_Information_System*

Constraint: Hospital cannot report exchanging medication information without an existing Drug Information System application

Syntax:
HealthEntities
and ((isSending some MedicationInformation)
or (isReceiving some MedicationInformation))
and ('has existing Drug Information System' value false)

Label 6: *Sharing_Patient_info_without_Client_Registry*

Constraint: Hospital cannot report exchanging patient/client information without an existing Client Registry application

Syntax:
HealthEntities
and ((isSending some Patient/ClientInformation)
or (isReceiving some Patient/ClientInformation))
and ('has existing Client Registry' value false)

Label 7: *Sharing_Referral_info_without_Provider_Registry*

Constraint: Hospital cannot report exchanging referral information without an existing Provider Registry application

Syntax:
HealthEntities
and ((isSending some ReferralInformation)
or (isReceiving some ReferralInformation))
and ('has existing Provider Registry' value false)

ConflictedHealthEntities Classes &Constraints

Label 8: Sharing_Scheduling_info_without_ProviderorClient_Registry

Constraint: Hospital cannot report exchanging scheduling information without an existing Provider or Client Registry application

Syntax: HealthEntities

and (('has existing Provider Registry' value false)

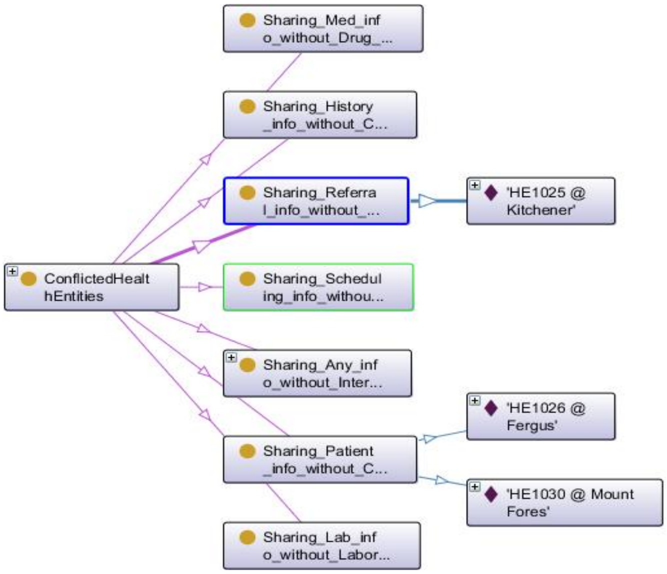
and ('has existing Client Registry' value false))

and ((isSending some SchedulingInformation)

or (isReceiving some SchedulingInformation))

The reasoner was activated to infer class members of ConflictedHealthEntities and its subclasses, and to check for invalid data. In total, three instances of potential data incongruity for the sample were identified (see Figure 24).

Figure 24. Instances of ConflictedHealthEntities Class



The instances suggest that one respondent has reported they send or receive referral information without using an electronic provider registry, two others that they are sending or receiving patient information without an electronic client registry. This is entirely possible in the current healthcare environment in Ontario and may indicate the need for changes to our constraints rather than erroneous information, for example the providers could be making referrals via email. It should be noted that conflicts are nothing more than a red flag in these instances. As crude measures of data quality, they represent an opportunity to engage with individual respondents in self-reported surveys, to determine whether the inconsistency is material.

For this and other uses of this data checking functionality, the surveyor would verify whether this was a result of 1) a transcription or data entry error, 2) misrepresentation of capabilities in either survey, 3) semantic discrepancies in survey questions or terminology (perhaps due to different people completing each survey, 4) temporal differences in survey completion such that one was completed later and therefore better reflects the status quo, 5) incorrect assumptions regarding mapping of ontology properties, 6) new technology or erroneous assumptions which require adjustment of class or property constraints.

A thorough understanding of the constraints associated with individuals in each sector, and the necessary applications which facilitate the exchange of each type of information improves the ontology’s accuracy in detecting data inconsistency. While not definitive for all data types and all respondents in this study, the ontology has demonstrated its potential for the application of automatic inferencing to the validation of eHIE data. Other opportunities for validation of the eHIE data using system-level technology performance measures in Ontario are discussed in the following section.

5.6.2 Validity of Comparative Health Technology Performance Measures in Ontario

Our literature review identified two measurement systems which indirectly provide information on healthcare providers' ability to share clinical information electronically; the OHA eHealth Adoption Survey and the HIMSS EMRAM® survey. At the time of writing, 639 hospitals in Canada participate in completing the survey and are provided with their EMRAM® score, benchmarks and other healthcare related IT reports (for instance in the U.S. hospitals are provided with an ARRA/HITECH ACT compliance scorecard)(http://www.himssanalytics.org/data/annualStudy.aspx).

Participants are required to update their progress annually, including providing an inventory of applications. The capabilities measured by EMRAM® are reported in 8 categories from 0-7 and report the need to prove health information exchange (HIE) capability at Stage 2 (though not use) through to reporting CCD (Continuity of Care Documentation) capability with other sites at Stage 7. The organization's limited publicly-available information suggests that by Stage 7 all hospital departments must have "complete EMR implementations across the entire hospital", but all lower stages can meet the stage criteria if all the application requirements are satisfied for at least one patient care service area – the scoring algorithm also assigns value to higher stage capabilities (French & Hoyt, 2009).

A comparison of scores reported for Canadian hospitals at the time of the survey for this research study (2010Q4) and current reported scores are provided in

Table 24. Progress between stages is minimal over the two year period and for the most part confined to movement between Stage 0 and 2 which focus on digitizing laboratory, imaging and pharmacy applications internally, with an acknowledgement that this may include the development of limited

health information exchange capability (not necessarily use). The main point is that progress year-to-year in the hospital sector is slow.

Table 24. Canadian Hospitals Variance between EMRAM® Scores 2010 Q4 and 2012 Q3 (% of hospitals N=639)

Stage	Cumulative Capabilities	2010 Q4	2012 Q4	Variance
Stage 7	Complete EMR; CCD transactions to share data; Data warehousing; Data continuity with ED, ambulatory, OP	0.00	0.00	0.00%
Stage 6	Physician documentation (structured templates), full CDSS (variance & compliance), full R-PACS	0.20	0.50	0.30%
Stage 5	Closed loop medication administration	0.20	0.30	0.10%
Stage 4	CPOE, Clinical Decision Support (clinical protocols)	2.20	2.30	0.10%
Stage 3	Nursing/clinical documentation (flow sheets), CDSS (error checking), PACS available outside Radiology	33.00	33.80	0.80%
Stage 2	CDR, Controlled Medical Vocabulary, CDS, may have Document Imaging; HIE capable	23.50	25.30	2.00%
Stage 1	Ancillaries - Lab, Rad, Pharmacy - All Installed	12.10	14.80	2.70%
Stage 0	All Three Ancillaries Not Installed	29.00	23.00	-6.00%

Source: http://www.himssanalytics.org/data/annualStudy.aspx

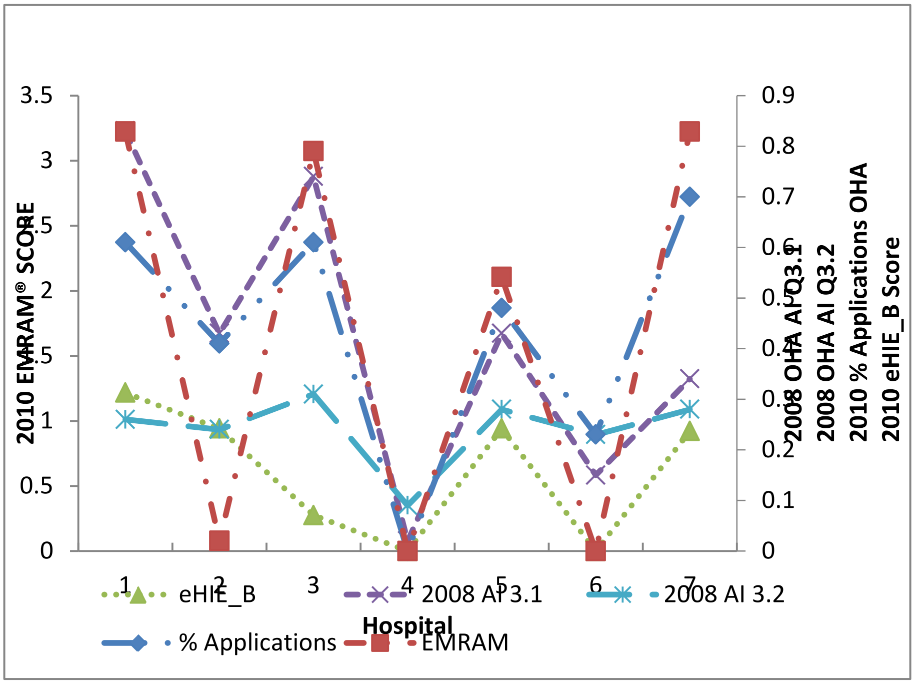
The EMRAM®, as the only widely used technology adoption benchmarking tool available to governors, funders and other stakeholders to measure progress towards EMR adoption, is a blunt tool. It is a ‘black box’ for which we have little understanding of its methodological rigour and it is designed to measure technology adoption as an end, rather than a means to effect the goal of making timely and accurate relevant information available for clinical decision-making whenever, and wherever, it is needed in the healthcare system to improve patients' health and quality of care. While EMRAM® may incorporate some measure of clinical health information exchange into its scoring algorithm these are not discrete, nor are they its focus, and we hypothesized that the data and therefore EMRAM® scores would not be correlated with hospital eHIE scores.

A comparison between [LHIN name withheld] hospital scores for the OHA Adoption Index, the EMRAM® and eHIE may identify a general correlation derived from the need to have clinical applications and infrastructure in place to digitize information before it can be shared electronically. However, we hypothesize this correlation will deviate for some hospitals depending upon such factors as their category (for instance, large community acute care hospitals would be expected to score highly on the EMRAM® whereas smaller hospitals which focus on continuing or chronic care would not), and geographic proximity to other hospitals (for instance a small hospital located close to a large academic hospital in an urban area, driven by the need to coordinate more efficient admissions and discharges, might be expected to score higher than one in a remote rural area).

As with the OHA Adoption Index only a small proportion of the EMRAM® scoring algorithm accounts for the elements which are the focus of the eHIE. In Ontario, the EMRAM® data is collected by the OHA; portions of the data submitted by member hospitals to the *Clinical Capabilities and eHealth Adoption: Technologies and Applications Survey* is included in the EMRAM® calculation. Data collected for the ontological validation of eHIE data in Section 5.6.1were analysed and a ratio assigned to each hospital derived from the total number of applications reported/total number of applications in the inventory (% Applications) to assess the correlation between this ratio, the EMRAM®, and other EMR adoption measures.

A visual comparison of the OHA Adoption Index Questions 3.1 ("Does your hospital corporation currently [or is it in the process of developing the functionality to] electronically share data outside your hospital corporation") and 3.2 (which focuses on interoperability between organizations to enable a shared HER), the EMRAM®, OHA Applications Inventory and eHIE_B measures (eHIE_A & eHIE_B scores are equivalent for our hospital sample) is provided in Figure 25 for each of the seven hospitals participating in this research study. In this graph we are able to visually confirm that, except for one instance, the data points from the OHA and HIMSS survey trend consistently with the eHIE indicator.

Figure 25. Analysis of Study Participant's Ontario Hospital IT Adoption Measures & eHIE



There is a significant correlation (r_s = .77, p<.05) between the eHIE_B score and the OHA Adoption Index Q3.1 (Inter-Organizational Data Sharing) score, confirming eHIE content validity. There is no statistically significant correlation between the other score pairwise comparisons, confirming both of our hypotheses regarding construct validity of our eHIE indicator. It should be noted that while there is a statistically significant relationship between these two measures, the sample is small and thus must merely be considered worthy of further exploration. Furthermore, the eHIE_B data point for Hospital 3 deviates from the other data points. This deviation may be related to data quality, or possibly represents a material difference that should be investigated further.

Data for the OHA Adoption Index indicator is no longer being collected, and no attempt is being made to capture interoperability measurement (as previously noted the EMRAM® indicator does not measure health information exchange). No comparable interoperability measures exist outside the hospital sector in Ontario for comparison of organizational and system-level results, therefore the eHIE provides a novel and complementary data point for evaluation of the progress towards the goal of having Ontario’s health services providers share health information to support clinical decision and effect seamlessly integrated care.

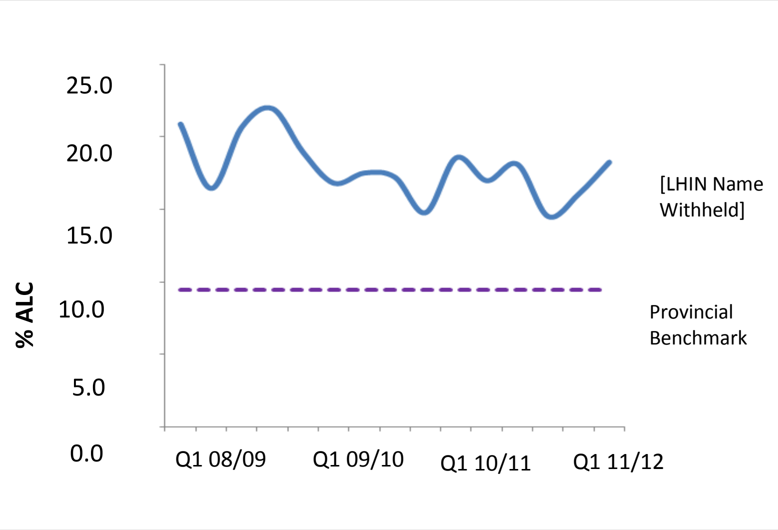
5.6.3 Comparison of Results with Publicly Available System Integration Data

We are unaware of any validated, reliable system-level indicators of integration in healthcare. The last independent and systematic healthcare system measurement in Ontario was conducted by the Health System Performance Research Network from 1998 - 2008. The reports focused on hospital performance, alternately concentrating on acute care, complex continuing care, emergency department care, hospital rehabilitation services, in-patient mental health, diagnostic care, women’s health and nursing. A Balanced Scored approach was adopted as the measurement framework of choice and yielded four common quadrants: clinical utilization and outcomes, financial performance and condition, patient satisfaction, and system integration and change (SIC) (Health System Performance Research Network, 2008). This collective of researchers acknowledges that unlike the other quadrants, there is lack of “accepted standard measures” (Pong & Grimwood, 2008, p 3) for system integration.

More recently, Health Quality Ontario (HQO) has suggested that alternate level of care days (ALCs) may be applied as a measure of healthcare system integration (Health Quality Ontario, 2012). ALC is variously described but in general is understood to measure the percentage of inpatient days that patient spends in an acute care hospital bed, after a physician has declared the acute stage of their treatment is complete. Where a health system is successfully coordinating care, and communications are timely, patients should receive services in settings most appropriate to their needs (the assumption being fewer healthcare resources are required as patients transition from acute care to home, or another less intensive care setting). The provincial ALC benchmark at the time of conducting the eHIE survey was 9.46% and remains the same in 2013 (Health Quality Ontario, 2012).

The [name withheld] LHIN’s ALC % performance over the period Q1 08/09 through to Q1 11/12 has ranged from over 20% to 15% , well above the provincial benchmark (Figure 26). This suggests that the low integration measures calculated from our survey data, and low overall system interoperability measure for eHIE in this region is consistent with this proxy measure for system integration.

Figure 26. Acute Care ALC (%) for [LHIN name withheld]



5.7 Summary

This chapter has presented the results of an expert consensus development process that identified three system integration performance measures. These measures were amalgamated into a survey developed to gather data which measured the amount of electronic clinical information being exchanged by a cross-sectoral sample of providers in a regional health system. In parallel, an ontology was developed to not only create a permanent representation of domain concepts in the form of a dictionary of terminology in natural language, but given the embryonic nature of this research, to clearly communicate the taxonomy for the entities, processes, relations, and properties in order to maximize its potential extensibility in future research. A test of this extensibility was conducted to validate the survey data quality using a third party, unrelated database of information for a small sample of the survey respondents.

A summary measure of the amount of information being exchanged in a regional health system was derived in a format that assumed all clinical information that can be shared is shared (eHIE_A) and also in a more conservative measure that allowed providers to control what information was considered suitable for sharing based on the context of their individual practice and organization (eHIE_B). The system eHIE_A scores ranged from 0 to .894 and for eHIE_B from 0 to .938 out of a possible score of 1, and were highly skewed with most providers sharing little to no clinical information electronically across the system. The highest scores emanated from the long term care sector. The system-level weighted average for eHIE_A was 0.07, and for eHIE_B was 0.12. Thus, the most optimistic measure indicates that 12% of clinical information was being shared electronically in this region.

Statistical analysis confirms a significant correlation between the amount of information being exchanged electronically in this system and respondent perceptions of system integration therefore the eHIE may be considered for use as a leading indicator of system integration.

Chapter 6

Discussion and Conclusion

In the previous chapters we developed a theoretical framework to describe the relationship between electronic health information exchange and healthcare system integration, proposed a measure of electronic health information exchange (eHIE), developed a formalized conceptual map of regional eHIE, with explicate assumptions and properties associated with those conceptualizations to assist with validation of the eHIE, and examined the relationship between the eHIE measure and integration within the regional healthcare system. In this chapter a discussion about the relevance and findings from this research study will be examined and compared to current thinking as outlined in the literature review and the theoretic constructs developed in Chapter 3. In closing, a brief review of the factors which limit generalization from this study will precede a discussion on the conclusions which can be made from the findings as well as the implications for research and industry best practices going forward.

6.1 Discussion

System-level health indicators have been collected by Health Canada and Statistics Canada since 1999 providing annual data to support decision-making related to the health of Canadians and their health care system. The Health Indicator Framework includes measures or information gathered from four quadrants under the headings: health status, non-medical determinants of health, community and health system characteristics and health system performance (Canadian Institute for Health Information & Statistics Canada, 2009). The Framework includes an impressive number of outcome measures from the health care system, yet the majority of them are lagging indicators, retroactively detecting system performance problems after they have had an impact on patient/clients. Ideally, one should select a mix of indicators, a balance of leading and lagging, outcome and process, to make measurement more sensitive and responsive, and allow active management of improvements to a system (Kaplan & Norton, 2001; Kaplan, 2001). To date, measurement of system-level integration has focussed on lagging indicators.

This study develops a theoretical foundation for a leading measure of healthcare system integration, the eHIE. This straightforward and inexpensive indicator provides a relative ranking of health entity’s interoperability that manifests itself as electronic health information exchange with other health entities in the system. The pilot study and analysis were able to measure the components of the eHIE and support its potential as a measure of integration at a regional or system level.

6.1.1 Synthesis of Findings

The trend towards more highly differentiated organizations or health entities requires the same health entities to integrate care with a growing number of independent care providers in order to deliver seamless, safe, and high quality health care. A number of factors determine the level of integration between entities in a healthcare system, however the literature supports the notion that timely sharing of relevant clinical information, while not sufficient, is a necessary component of an integrated health care system (Suter et al., 2009).

This research study, both theoretically and empirically, supports the link between electronic exchange of clinical information between organizations in a network and seamless care through integration of those same organizations. In particular it makes two notable contributions. First, a method to measure the extent to which health care organizations exchange health information is developed from theoretical constructs and is operationalized in a live setting. Second, the metric provides, for the first time, empirical evidence that there is a positive relationship between the extent to which health organizations within a health system exchange information and the quality of care provided by that health system – something that has been asserted in the literature but has not been proven to date.

The study conceptualizes a meaningful and granular framework for understanding health information exchange, develops a framework and measurement model to connect regional electronic information exchange and system integration, and applies it in a regional health network in Ontario, Canada. The performance measurement model guiding the conceptualization of electronic health information exchange and integration (see Figure 6) uses Donabedian's health service quality framework to structure the connection between networks of health entities and their operational characteristics (such as organization type, and potential impact of interoperability based on their the numbers of patients/clients and exchange partners), and the system integration facilitated by electronic health information exchange, that will produce the system outcome of "seamless" patient care.

This study focusses on the concept of interoperability manifested as electronic health information exchange and determines that interoperability is highly nuanced and, by extracting the constituent components, is measurable. It determines that some types of clinical information are shared more often than others, and that some sectors of the system are exchanging information more than others, but that overall the level of electronic health information exchange remains low despite sizeable investments of resources. Furthermore, participants in the regional network report that the ability of the system to deliver an optimal level of seamlessly integrated care is also commensurately low. Previous researchers' hypotheses that information technology mediated information exchange is a pre-requisite for health system integration (Kodner, 2009; Lee & Francis, 2011; Protti, 2013; Suter et al., 2009) are supported by the discovery of a statistically significant relationship between the two in this study. The magnitude of the correlation coefficient is consistent with our understanding that a profusion of factors influence healthcare system integration.

Green & Moehr (2000, p319) have suggested that interoperability may be a "crucial indicator" of system performance and Kasunic & Anderson (2004, p16) have stated that "measuring, assessing, and reporting interoperability in a visible way is essential to setting the right priorities". The findings in this study supports the hypothesis that health information exchange through information systems interoperability, while practically invisible to stakeholders interested in formative evaluation of system performance, is measurable, reportable and "visible" as a result of its impact on system integration.

6.1.2 Study Findings in Relation to the Literature

Previously, inter-organizational electronic information exchange measurement in healthcare has been sector specific, incidental, and functionality generally referred to as being present or not present. The eHealth Adoption Survey last published in 2008, was such an instrument, and also focused solely on hospitals (Ontario Hospital Assocation, 2008, p.14) and their internal systems. In this study a more granular framework and measure of bi-directional health information exchange is conceptualized, a measurement model for interoperability developed that ensures important components of the exchange are accurately represented and separately counted. The measure is applied across the care continuum not just one sector, and allows participants to determine the optimal level of interoperability for their organization and level of integration for their healthcare system. In doing so it empirically supports previously hypothesized linkages between inter-organizational electronic health information exchange and health system integration (Halamka, 2013; Harno, Ruotsalainen, Nyakanen, & Kopra, 2009; Suter et al., 2009).

The conceptualization of the health system performance measurement domain is complex and requires deconstruction in order to better understand its myriad influences. Here the focus is health system integration and interoperability, yet the influencing literature comes not only from health but also business, computing science and the military where the global compact similarly calls for the interoperation of heterogeneous information systems due to increasing expectations of public accountability, and operational efficiency. Thus the components of the electronic health information exchange indicator (eHIE) emanate from a broad scope of theoretical constructs and domains. Liang et al.'s (2004) measure of inter-organizational document exchange identified volume, diversity, breadth and depth of information flows. Labkoff & Yasnoff's (2006) degree of usage was the basis for our “impact” factor at the system level that accounts for the potential influence of a health entity’s health information exchange activity. Adler-Milstein et al.'s (2008) conceptualization of bi-directional exchange activities, and the scoring methodology and summary indicator reporting from the OHA eHealth Adoption Survey were also considered when developing the eHIE. This cross-disciplinary support for the measurement framework suggests the findings from this study will have relevance beyond the borders of healthcare.

Previously, the healthcare sector has struggled to conceptualize and measure integration, despite its being a universal goal of major western healthcare delivery systems. While this is not unexpected in such a dynamic and complex system, the lack of consensus on definitions and frameworks has created problems in measurement conceptualization; as a result a definition associating its outcome with a seamless and unified system across the continuum of care for patients/clients was adopted for this study (see Section 2.2.1). This impacted the scope of our study, incorporating not only the most studied health entities and sectors in the system such as physicians and hospitals, and acute care, but also increasingly important partners in the healthcare network such as long term care homes, pharmacists and public health departments. Ahgren & Axelsson's (2005) concept of a continuum of integration, Kodner's (2009), Macadam's (2008) and Leutz,'s (1999) integration frameworks all influenced our archetype of integration, and the selection of a Likert scale to measure respondents' integration with the system. The creation of a parsimonious summary measure of interoperability (the eHIE) allowed us to test the relationship between two equally nuanced and complex concepts.

Not surprisingly the study identified that providers rate the integration of the health system as modest, with over 70% ranking integration as slight or non-existent. This finding is entirely consistent with the literature (for example Schoen et al., 2012) but is correlated with a detailed and comprehensive analysis of the process associated with a critical component of seamless care, health information exchange. Thus this measure may provide Green and Mohr's "crucial" indicator for priority-setting and resource allocation to advance adoption levels of information and communication technology beyond the rudimentary, and into an era where critical pieces of information for patient-care and decision-making are shared wherever or whenever they are needed.

Survey results provided general information about the use of information and communication technology (excluding fax or telephone) amongst the respondents with 90% indicating they manage administrative functions such as billing and scheduling electronically, and 69.3% to manage patient clinical information. The rate for family practitioners/general practitioners managing clinical information electronically was 66.7% (n=54) and for physician specialists was 45.2% (n=42). This is higher than those reporting in the 2010 National Physician Survey (College of Family Physicians of Canada, 2010) but can be accounted for the fact that this survey asks whether or not an electronic system is in use, whereas the National Physician Survey speaks directly to the use of EMRs to "manage your patients' chronic conditions"; clinical management being a more sophisticated capability beyond the use for medical documentation. The 2011 National Physician Survey question reported that paper charts are used exclusively by 40.7% of family physicians and 34.1% of specialists (College of Physicians and Surgeons of Ontario, 2011) . The same survey reported that 9.9% of family physicians, and 6.6% of physician specialists have an external interface with a pharmacy. A study by (Schoen et al., 2012) reports that 14% of physicians report being able to electronically exchange patient summaries and test results with doctors outside their practice. This study indicates that primary care and physician specialists report a mean eHIE of .141 or 14.4% and is consistent with the Schoen et al.study.

Paré & Sicotte`s (2001) study of health information technology sophistication scored Ontario and Quebec hospitals as a 2 out of 7 (using a Likert scale) for their ability to share information externally. The mean of the two eHIE scores (eHIE_A=0.07 and eHIE_B = 0.12) of 0.095 is below that of Paré & Sicotte, and remains low when hospitals alone are examined with an eHIE_A and _B mean score of 0.159. Closer examination shows that their measure of external information sharing refers to the “interface between patient care systems and external entity’s computerized systems (Clinic, other hospitals)” and thus is restricted to only inter-hospital exchange which, with their greater investment in information systems and more sophisticated in-house technical support, might be expected to have more advanced information exchange capabilities.

Other U.S. studies have alluded to significant differences in EMR adoption by physician specialty with psychiatrists, dermatologists, pediatricians, ophthalmologists, and general surgeons less likely to adopt EHRs than their counterparts in family medicine (Grinspan, Banerjee, Kaushal, & Kern, 2013). The sample size of this study did not allow reliable reporting by physician specialty. The only other systematic collection of information related to healthcare provider electronic information exchange at this time is the voluntary inventory collected by HIMSS; this framework provides an incomplete picture of the flow of clinical information to and from healthcare providers and is currently restricted to use in the hospital sector.

HIMSS's HIE Common Practices Survey (2009) sought to better understand Health Information Exchange (HIE) organizations` activity in the United States by gathering information related to their architecture, software, and the types of information exchanged. Results indicated that “bi-directional data exchanges occur in 71 percent (71%) of participants, one-way in 29%. All one-way exchangers indicated they would exchange bi-directionally in the future. The predominant information for exchange was “lab results and prescriptions”. Responses were self-reported, however there was no attempt to determine the extent of health information exchange, that is, their binary response of yes/no, merely indicated the presence of exchange activity. While measurement of data exchange activity is preferable to the measurement of exchange capability alone, without an estimate of the amount of information being electronically exchanged in comparison to the total volume, it is not possible to measure progress towards system-wide interoperability.

Most respondents in this study (61.7%, n=111) report exchanging some type of information electronically with other health service providers outside their own organization, however the mean eHIE at 0.095 indicates that this is not a reliable indicator of the amount of clinical information that should be shared electronically. The study is able to conclude that that attitudes are not a substantial barrier to greater electronic information exchange and interoperability, and these results are supported by previous research in the domain (Wright et al., 2010).

Finally, we have created and used a formal specification of the health performance model using an ontology, and populated the ontology with instances from the regional survey. While ontologies are common in biomedicine and increasingly used in designing controlled vocabularies (Cimino, 2012) and reference terminologies (Burgun, 2006), there is little research into the use of upper level ontologies applied to health information systems themselves (Raghupathi & Umar, 2011, p. 286), or in support of healthcare performance measurement (Beyan & Baykal, 2012, p.202). Without shared or standardized semantic and lexical models, reliable and accurate comparison of health performance data across sectors and geographic borders is unachievable.

Ontologies may contribute to semantic interoperability between performance management databases in health care and other social sectors and could eventually lead to the mapping of large databases of performance metrics across the continuum of care and across sectors. The ontology developed for this study created a vocabulary of terms in natural language, a visual model with classes, properties of each class describing various features and rules associated with those properties, and the ability to logically test the classes and properties using a reasoner.

By linking two databases, namely the survey data from this study and data from an unrelated database, we were able to demonstrate a novel method of testing the validity of the collected data using the ontology, something that was notably absent in other studies. The lack of validity testing in these studies has as much to do with the context of the field in which the research is conducted (such as the limited participation of busy healthcare providers and concerns over confidentiality of information), as it does with the rigour of the methodology. Much of the information that is required to validate organizational and system level electronic information exchange is maintained in proprietary databases in the healthcare sector, for instance each health entity will have a system network log that identifies data inflows and outflows.

Furthermore, access and information flows are rarely managed or audited, as is the case with most health providers using paper-based information exchange systems. Where institutions are publicly funded to deliver care there are expectations of performance accountability, however information with individual or organizational identifiers that would allow researchers to validate responses is rarely made public.

6.1.3 Reliability, Validity & Generalizability

The reliability and validity of the quantitative findings were addressed using appropriate statistical techniques. The credibility of the results were established through triangulation that involved the use of multiple methods; extensive literature reviews, the establishment of theoretical frameworks, use of a panel of experts, and empirical data from the field. Development and testing of the framework and questionnaire were iterative processes (see Section4.4.3). Final scores were not confirmed with respondents as data quality or missing responses were addressed at the time of submission. A comparison of this study's results and the OHA eHealth Adoption Survey and the HIMSS EMRAM® survey confirmed that the data points for a similar time period are consistent and deviations explainable.

The ontology allowed for queries and inferences to validate the logic of the interoperability measure by setting constraints on such concepts as HighIpactEntities and HighIntegrationEntities derived from our performance framework, and automatically populated these subclasses with instances collected from the survey. A visual model of the domain with classes, properties of each class describing various features and rules associated with those properties, was used to check the logical consistency of imported data. This functionality was an important complement to the manual checks for outliers performed by the researchers – logical inconsistencies were immediately visible. Flexibility to extend a conceptual model, and classify new concepts (for example new health entities that will provide care in the future or novel types of clinical information such as DNA sequences) is a hallmark of ontologies. This extensibility not only allows the ontology to change in response to a dynamic environment but also ensures that new definitions and concepts are immediately updated across all linked ontologies.

By identifying an unrelated database with common instances with the survey (namely the seven hospitals in the region of interest), this study demonstrates how an ontology might be used to further test the validity and quality of collected data. Using a small sample from the OHA's *Clinical Capabilities and eHealth Adoption: Technologies and Applications Survey 2010* a set of classes in the ontology was created with constraints designed to identify hospitals which had reported the electronic sharing of certain types of clinical information in the original survey, but which had not reported the presence of applications which are believed to be required for that functionality. The reasoner identified some inconsistencies in data reporting across the instruments; investigating the source of those inconsistencies could be the subject of future investigation. Much of the performance data collected from the healthcare sector is self-reported not automatically generated, not surprising given the sector's on-going reliance on paper records. Executing audits for logical consistency between databases of self-reported data using ontologies and reasonsers may significantly increase the productivity and accuracy of data validation.

6.2 Strengths and Limitations of the Study

There are a number of factors that contribute to the strength of this study. A robust theoretic framework and an extensive cross-disciplinary review of the literature firmly grounds the work in foundational concepts, and adds to our understanding of interoperability and system performance measurement. This theoretically grounded approach to practically measuring information exchange produced tools (such as the questionnaire, measurement indicator and ontology) that are evidence-based as well as endorsed by experts in the field and practitioners.

For the first time, a measure of electronic health information exchange and health system integration has been calculated that incorporates ALL healthcare providers in a network. As previously noted, most other studies focus on one domain or discipline. The resulting `picture` of interoperability and integration presents a full accounting for activity of a whole system, rather than a small sub-section.

The survey was carefully constructed to gather a relevant but parsimonious dataset, the frameworks focus only on those concepts that the literature suggested was material to our measurement model. For example, our questionnaire asks whether or not respondents are using the EMR for client/patient health information management but it is not a component of the eHIE measurement. In 2009, Schoen and colleagues identified that primary care physicians in some countries adopted information technology at higher rate and to a higher level of functionality than others (for instance New Zealand, Australia and the United Kingdom). Despite this capacity most continue to struggle with inter-organizational interoperability of those systems (Schoen et al., 2009, 2012), suggesting that EMR adoption is a necessary precursor to interoperability, but not material in eHIE calculation, and thus it was excluded from the measurement model.

A few limitations restrict the generalizability of the study. A census sample would ideally provide a more accurate and comprehensive measure of information exchange and integration. However we are aware of no instances where this has been achieved, on the contrary the study achieved return rates equivalent to or better than other studies in the past. Adair and colleagues (2005) have identified that proving causality between constructs requires accumulating a number of observational studies such as the one conducted in this research, to gain better insight into a phenomenon before conducting more rigorous experimental designs. Therefore, despite its exploratory design, this study builds on the work of others towards an understanding of the domain that will facilitate increasing experimental rigour.

While attention must be paid to efficient and effective infrastructure to support the exchange of relevant clinical information between health care entities (Markle Foundation, 2004), this study did not attempt to inventory or measure the technological architecture of health care entities or regional networks, nor to understand the factors that impact adoption of information technology. That work has been completed in some healthcare sectors, and in many cases provides little insight into whether or not clinical information exchange is actually occurring; those with sophisticated hardware and networking capabilities can remain as isolated as providers with none. This study`s focus was to identify whether health entities have the capability to share clinical information electronically, at what level they are sharing, and whether this capability improves perceptions of integration with the system. Further research will be required to understand whether and how health entities can be encouraged to improve electronic information exchange and whether other organizational variables impact electronic health information exchange.

The theoretical framework is capable of informing the development of a clear and understandable data collection instrument, and collected data demonstrated correlation between the proposed index of health information exchange and system integration; further refinements of the instrument and testing of its reliability and sensitivity over time would be warranted.

The sample population for the study includes health entities whose primary function is health service delivery or coordination, are primarily publicly funded, and who deliver those services within a region where there is an expectation of coordinated care. Health care providers are notoriously time-constrained, as a result tradeoffs were made between the complexity, breadth and depth of data collected, and length of the survey instrument. The regional system selected for this study may not be representative of the entire population of regional health systems in Ontario, or elsewhere, therefore the results may be limited in their generalizability. Furthermore, the selected region operates in the context of Canada's publicly funded, not for profit health system rather than in a for profit environment where unique incentives or barriers to the sharing of data/information outside an organization may be present; results should be interpreted accordingly.

The survey required judgments by participants on relatively abstract constructs; despite involving participants in the development of the instrument and providing respondents with information to improve their understanding of the questions, it's possible that subject ambiguity may have influenced their answers. To gather "perfect" information on the percentage use of electronic information exchange, would involve examining system logs of all devices to determine the percentage of clinical information being exchanged digitally, and following each member of the health entity and their staff at various locations to determine the extent of the totality of information transferring in and out of the facility. Until the entire system is "paperless" with interchanges logged and measureable electronically, even those entities with high interoperability indexes would require some on site validation of paper records transfer. The assessment of the entity's electronic exchanges is subject to the quality of their selected respondent's knowledge of the organization and data flows. While method and social desirability bias may have been a factor in this empirical research (Podsakoff et al. 2003), studies have shown that employees are "shrewd judges of the effectiveness of organizations in which they work" (Donabedian, 1966, p.698).

Finally, given the innovative nature of this research in the health care domain, we have focused on exploring the face and content validity of the constructs through the input of industry experts and feedback from field tests, feasibility of the data collection instrument through the successful implementation of a survey, and correlation with perceptions of health system integration using accepted statistical methods. Further research will be required to establish the instrument’s reliability over time. Despite these limitations, this study provides an important contribution to both the theory and practice of health system measurement in a novel area.

The following section explores future directions for research arising from this study. Its intent is not to restate the findings of this study but to prompt a discourse amongst my colleagues on its inferences and explore opportunities for its use in advancing our understanding of the relationship between interoperability, integration and health system improvement.

6.3 Implications and Areas for Further Research

The indicator developed in this study acknowledges the dynamic nature of technological innovation and the vast untapped potential for the expanded use of information and communication technology in the health care sector. Consequently there is no fixed denominator, and assuming that the diagnosis, treatment and care of disease is incrementally impacted by new technological innovations, this flexibility is important in order to accommodate the addition or deletion of types of information, novel processes for sharing clinical information, and future categories of healthcare providers over time. The information taxonomy and conceptual model which contributed to the formal ontology will benefit from updates and edits commensurate with that changing environment. Moreover, further work on establishing and managing performance measurement ratios in arithmetic, natural and logical languages will reduce misunderstanding and calculation errors, and has the potential to lessen concerns over large, isolated datasets with little practical utility.

Kuziemsky & Weber-Jaknke (2009) and others have suggested that there is wide variability in the maturity of national e-health systems and in particular their ability to electronically exchange health information; this due in large part to the complexity of standards at the information level, and rapidly changing knowledge at the semantic level. The embryonic phase of health system electronic information exchange suggests that there may be little to lose from focusing on system-level collaboration to develop common vocabularies and standards which facilitate machine-mediated semantic interoperability between health information systems. At the same time, this study identified that, even within the same disciplines and sector, provider perceptions of what information to share, and where, is quite varied. Research that provides insight into whether that variation is driven by legitimate operational conditions or personal bias is warranted in order to identify the resources required to address lagging sectors.

The advent of large scale health information exchange networks is raising legitimate concerns about the protection of privacy for both patients/clients and the professional who care for them (Geissbuhler, 2011). This concern may be of peculiar importance to the healthcare sector where the most personal information made available to the wrong people or in the wrong context, has the capacity to impact the lives of ordinary citizens in potentially catastrophic ways such as the denial of benefits or employment, or social stigmatization. Future research into the measurement of progress towards health system interoperability might include investigation into how lock-boxed information impacts the sharing of clinical information, and as a result, the delivery of integrated and seamless care.

Recent commentary has suggested that a plethora of clinical communications are flowing between healthcare providers through smartphones (Falk, 2011) as a result of wireless or mobile information communication, referred to as m-health; rather than contradicting the results of this study, further research should be conducted to determine whether these streams of digital clinical information are sharing information between healthcare entities or whether they constitute intra-organizational information flows which would remain inaccessible to providers up or down the healthcare care continuum.

This study's examination of interoperability frameworks revealed levels beyond technical interoperability that focus on data sharing, and address interoperability issues from the perspective of organizations' capacity and readiness to work with partners in their networks (such as the ISO/European Committee for Standardization (CEN), 2009, Framework for Enterprise Interoperability). Technical and semantic interoperability concerns are addressed but the focus turns to conceptual barriers that impact semiotic interoperability such as conflicting "culture, value expectations or operational concepts" (p.11). The key to an accelerated interoperability agenda for regional networks of healthcare providers may in fact lie in a research agenda that examines organizations' semiotic incompatibility.

Finally, Marquart & Konrad (1996) note the importance of developing comparators in order to objectively examine integration projects. Further testing of the validity and reliability of the eHIE by administering the survey across more than one regional health system would provide multiple data points for system-level comparison of integration metrics. Reliability testing of self-reported organizational-level metrics would provide support for our assumption that respondents are accurately representing the status quo and sentiment of the health entity.

6.4 Conclusion

Brailer (2005, p. W519-20) refers to information “as a mechanism for integration” that could “virtually tie together a network of providers so that fundamental operational, clinical and financial synergies could be realized”. Progress towards integration has been described as “inadequate and disappointing” (Protti, 2013) and the lack of electronic health information exchange in Canada as the result of Infoway`s focus on national rather than regional interoperability (Rozenblum et al., 2011). Ontario LHINs claim technological sophistication is contributing to greater information movement between healthcare providers and sectors (Waterloo Wellington LHIN, 2012), yet how much information is being exchanged, by whom and to what effect, has previously been unavailable.

In this study we have demonstrated that it is possible to conceptualize and measure system-level electronic information flows between diverse healthcare entities providing clinical services to regional populations. These flows are theoretically and empirically linked to positive perceptions of integration amongst the entities who demonstrate higher levels of interoperability. The framework and indicator developed, pilot tested and reported in this comprehensive research study has established a method for measuring electronic health information exchange and has substantiated its role in system-level integration. The performance measurement ontology provides an enduring artifact which helps to clearly communicate the concepts, and facilitates validation of data and visualization of the domain. All improve the likelihood that this performance measurement tool can be communicated, understood, accepted by stakeholders and adopted for use.

In spite a legacy of commissions and reports advocating for greater health services integration in Ontario (The Ontario Health Services Restructuring Commission, 2000), the perceptions of entity representatives in this study indicate that regional health systems at least, remain poorly integrated. The majority of health care providers in one of those systems has little capability to share patient clinical information electronically. Premkumar & Ramamurthy (1995) suggest that a large volume of information must be exchanged to support “tight” relationships between organizations and as a result it is unlikely that integration objectives will be achieved within in the near future until a critical mass of electronically available, reliable, clinical information creates a compelling reason to access and lobby for greater investment in and access to interoperable health information systems.

In light of this evidence, more upstream research is suggested to identify and prioritize factors beyond monetary resources, which spur the ability of electronic health information systems to accurately communicate meaningful and relevant information without the need for human intervention, and to ensure that this is done in a way which supports the clinical workflows of an overwhelmingly supportive health provider community.

In conclusion, it is important to remember that interoperability is not an end unto itself, as in other industries it is merely a state or process which is required between health entities and their information systems in order for consumers to experience seamlessly integrated care. The eHIE index developed in this study provides a system-wide measure of interoperability manifested as clinical health information exchange. It is agnostic to provider type thus ensures that all providers, whether a large academic health system or a small rural pharmacist, are accountable for their ability to communicate electronically with systems which hold key information for the care of their clients. This equity in accountability and need to understand the capacity for electronic health information exchange at all points in the healthcare system informs effective policy-making and resource allocation in our pursuit of seamlessly integrated care. As complex adaptive systems, healthcare systems are dynamic and open to correction; the use of leading or proximal indicators to determine the need for mid-course correction in our quest for system-level electronic health information exchange and seamlessly integrated care would be a prudent use of resources.

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Appendix A. Nominal Group Process - Pre-Meeting Materials

Introduction

The intent of this summary of selected literature is not to provide our expert panel with a systematic review. It is, instead, intended to situate the project in the context of the healthcare domain and previous research in the area, and to suggest potential frameworks and dimensions that will expedite the process of selecting indicators during our consensus building discussions on Monday.

Background

The successful integration of systems, which allow electronic access to timely information and data sharing between entities, has the power to radically change organizational operating environments (1). In fact, facilitating the flow of information across heterogenous systems and applications is one of the more pressing issues for organizations across all sectors (2) including healthcare. Information exchange, enabled by technology, is a necessary component of health system integration (3,4), creating efficient links through which data and information can be liberated from its originating source and flow to other healthcare providers.

Yet outside of acute care hospital settings there has been little research in Ontario to document or categorize the type of information exchange which occurs between healthcare service providers, nor to measure its collective impact on the system. Without this information, assessment of the value of billions of dollars of investment in information technology which have flowed into the Ontario healthcare system over the last decade (5), is challenging.

Canada Health Infoway has committed to building an infrastructure to support the pan-Canadian flow of patient data between healthcare providers (6,7). The Province of Ontario has also invested heavily in eHealth infrastructure through global funding, directed project financing, and adoption incentives to key practitioners such as primary care physicians. Many of these groups, to a greater or lesser extent, assess the success of their individual IT projects.

Investigation of the system-level impact of information technology, however, is less common; this is the focus of the MEIE research project. MEIE is focused on creating a system-level metric, or set of metrics, which help to better understand the impact technology has on the electronic flow of clinical information. Describing the “who”, “how often” and “type” of health data which is being shared across the continuum of care, will demonstrate whether the goal of having providers with the right information, at the right time and in the right place in order to optimize clinical decision-making, a goal of an integrated system, has been achieved.

This summary will identify a few frameworks and indicators which have informed, or have the potential to inform, the development of indicators which measure the exchange of electronic information. Due to the notable lag in adoption of information technology in healthcare (8), and the inter-disciplinary nature of health informatics, we extended our literature review beyond the bounds of the healthcare system.

Methods

A variety of search strings[6] were used to locate academic, peer-reviewed literature using search engines such as SCOPUS, PubMed, EMBase, ProQuest, INSPEC and Google Scholar. The search was not restricted to medical or health databases given the multidisciplinary nature of the topic. Hand searches were conducted of selected citations. Gray literature was also investigated. Numerous articles were located in each of the healthcare integration and interoperability domains; scant literature was located at their confluence, related to the measurement of electronic information flow between healthcare providers.

Selected Findings

Classifying Systems' Electronic Information Exchange Capability or Interoperability

Integration and interoperability frameworks were investigated to provide a little context before we select indicators to measure electronic inter-provider information flow. Not surprisingly there was a relative abundance of literature on interoperability frameworks from the military (NATO, U.S. Department of Defence). System Integration frameworks were less abundant but there is a wealth of system integration literature in the policy, business, computing science and healthcare domains. Appendix 1. outlines a selection of conceptual frameworks which describe the continuum; from organizations or entities which are isolated in a system, through to those which are fully integrated or interoperable. It should be noted that both quintessential states have changeable meaning depending on the perspective of the observer, but perhaps more importantly due to the dynamic influence of new technologies and our evolving understanding of what it means to be "integrated".

Unquestionably, the first step towards electronic integration, a technology infrastructure must be in place and configured to share data. This is a necessary but not sufficient condition for an electronically integrated healthcare system. Absence of that technological infrastructure denotes an isolated system in most interoperability frameworks (see Appendix 1). Creating the means for information to flow between providers represents the technological "ground zero" for virtually sharing of clinical data. The intelligent sharing of appropriate information (right information, right time, right place and right assumptions) in a dynamic web, what Tolk (9)describes as "conceptual interoperability", is currently the idealized goal. Ontario's healthcare system (and the sample we measure for our pilot study) will fall somewhere between these two points.

Indicators, Objects or Constructs Associated With Inter-Provider Electronic Health Information Flow

A small number of articles, which directly informed out research, were located in the peer-reviewed and gray literature. Foldy (10) describes an internet survey to inventory health information exchange (HIE) "projects" across Wisconsin. This study was representative of a growing body of

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[6] One such example: (measur* OR perform* OR metric OR assess*OR framework OR inventory) AND electronic and (information OR data OR system) AND (flow or exchange OR shar*OR interchange) AND health

literature on regional HIEs in the United States, where there is a growing focus on connecting healthcare providers regionally. Organizations in the Foldy study were asked to comment on a number of characteristics of the HIE projects, such as who the information users were (primarily centralized public health registries and clinical care providers). Each respondent (N=21) rated the stage of development of their projects. Their rating options included:

i. Stage 1 – Recognition of the need for health information exchange
ii. Stage 2 – Getting organized
iii. Stage 3 – transferring vision, goals and objectives to tactics and business plan
iv. Stage 4 - Implementation – technical, financial and legal
v. Stage 5 – Fully operational health information exchange
vi. Stage 6 – Expansion

The Ontario Hospital Association's eHealth Adoption Clinical Capabilities Survey (2008) uses a similar framework for hospitals to rank interoperability functionality, with respect to a number of clinical "objects" (such as discharge summaries), in their annual on-line questionnaire. The progressive ranking scale is not dissimilar to that described in the Foldy study. The hospital identifies if they are currently able to electronically share data: 1. outside their corporation, 2. with consulting physicians in the community (GP, FHT, etc), and 3. data with other healthcare organizations (CCACs etc.). A "Yes" response to any of these questions requires that the hospital identify which of the following objects are shared in that arrangement:

a. Admission histories?
b. Discharge summaries?
c. Patient referrals?
d. Drug profiles?
e. Lab results?
f. Diagnostic images?
g. Reports (imaging, surgical, procedural)?
h. ER/EED visit encounter summaries

The progress (or "functionality") towards sharing these objects electronically is then assessed further using the following sequential legend:

1. Not considered - is not being considered for planning or procurement
2. Identified – becomes part of the strategic IT plan
3. Acquired – the procurement process is initiated
4. In progress – the functionality is being implemented
5. Pilot/implemented – the functionality is in production
6. Mostly implemented – the functionality is mostly implemented
7. Fully implemented – there is no other usual way to perform the functionality
8. Not applicable – not relevant to the facility i.e. the hospital does not have an emergency department

In perhaps the most salient study, Liang et al.(11), investigated electronic data interchange (EDI) usage by Beijing's hospitals (N=57). Using four dimensions collectively derived from previous studies (12,13) the authors aggregated the metric results to provide a comprehensive description of the flow of electronic objects between hospitals and their stakeholders. The metrics used were:

1. Volume – the ratio of documents exchanged, measured by # documents exchanged by EDI/ # of all documents exchanged via all communication channels
2. Diversity – the number of different types of documents exchanged by EDI

3. Breadth – the ratio of trading partners with whom they shared electronic documents and the total number of all trading partners
4. Depth – measured using a three level metric to demonstrate increasing technical competency: data, data + text, and data + text + images.

Finally, Labkoff & Yasnoff (14) identified four "key requirements" for complete functionality of a community health information infrastructure that might suggest further measurement dimensions for the MEIE study. The requirements were:

1. Completeness of information
2. Degree of usage
3. Types of usage - such as patient care, public health, clinical research, quality improvement and healthcare operations
4. Financial sustainability – particularly salient for many regional health information infrastructures or exchanges which are often self-funded by partners

Other Directional Constructs Which May Measure Electronic Information Flow between Providers

Another potential dimension of interest to the MEIE research relates to the directional flow of information and its influence on data exchange between system providers (our research will include a component where data flows are "mapped" to visualize the exchanges between providers). Information systems can be used to publish information (push it out onto the web), receive information (by actively inviting it, or passively accepting it when offered) or retrieve information (by actively pulling it down for viewing. There is variability between providers in each of these dimensions, across organizations and sectors; collecting this information might provide further descriptive power to the location of information integration bottlenecks i.e. information might flow into an organization or entity but not flow out in the form of shared or published information.

Finally, when considering inventories of inter-provider information flow, one might keep in mind that the data preferences of attending clinicians, will greatly impact on what and how much information is exchanged. That is, we have to consider that while 100% of information could be exchanged, much less than 100% is required for thoughtful, informed, evidence-based clinical decisions. A number of researchers have documented clinician preferences for health data which is critical to their practice. Using an expert review panel, Overhage (15) proposed that records of ambulatory and emergency visits, inpatient discharge summaries, and lab data would be most useful (with 70% agreement or more); less important (30%) was prescription information.

The lack of interest in prescriptive information in the Overhage study contrasted with a study conducted by Walker et al. (16). In their study of U.S. healthcare information and exchange, researchers reviewed the value of electronic data flow between providers and the "five stakeholders they most commonly exchange information", namely independent medical laboratories, diagnostic imaging centres, pharmacies, payers, and public health departments. Kaushal et al.'s(17) work jibed with this finding when they identified several critical functional information requirements for a national health information network that included inpatient and ambulatory results viewing and prescription acceptance by pharmacies.

Conclusions

Healthcare in Canada is facing the prospect of a "perfect storm" brought about by shifting demographics, key health service provider shortages, increasing chronic diseases and their management costs, consumer demands for complete access to their health information and involvement in care decisions, fragmented healthcare services, and concerns about quality and avoidable errors.

A total of $121.6 billion was spent on health care in Canada in 2008-09[7], a 6.4 per cent increase over the previous year. The average total increase in expenditures for all governments (federal, provincial, territorial and local) was 2.5 per cent while their combined revenues shrank by 2.1 per cent. Clearly, “business as usual” is an unsustainable paradigm. Health information technology has the potential to facilitate fundamental change in all facets of the healthcare sector from prevention to palliation. In particular, liberating relevant clinical data from isolated systems to allow its use in improving the timeliness, quality and reliability of care, has the potential to improve collaboration and integration across the continuum of care and ultimately reduce the cost of delivery (18).

To date, there is a paucity of literature on the impact IT investments have had on electronic information exchange capabilities between providers and the level of system integration. Integration and interoperability frameworks have been identified to provide context for the identification of metrics which could be considered to measure inter-provider electronic information exchange. Potential indicators and units of measure, some with empirical evidence of use, have been identified.

The information from this summary should inform the views of the expert advisory panel, in the nominal group process which is being used to help select indicators, and development of a tool to gather data for a pilot study. Information and analysis of the pilot study results will help determine the indicators’ effectiveness as a measure of system-level inter-organizational information exchange and integration. It is hypothesized that a regional pilot study will reveal a broad continuum of system-level interoperability and thus information integration.

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	Isolated Systems		→		**Fully Integrated/Semantically Interoperable Systems**
Organizational Interoperability Maturity Model (19)	Level 0: Independent organizations	Level 2: Ad hoc arrangements	Level 2: Collaborative organizational interoperability (some shared goals but separate organizations)	Level 3: Integrated shared value systems (some interoperability and minimal links to home organization)	Level 4: Unified (Organizational goals, value systems, command structure & knowledge shared across system)
Levels of System Interoperability (20)	Isolated systems (manual re-entry)	Connected systems (homogenous exchange i.e. data file transfer)	Distributed systems (heterogenous exchange i.e. LAN or common operating)	Integrated systems (shared applications & data i.e. WAN)	Universal systems (enterprise wide shared systems, multi-dimensional topologies)
NMI (NATO C3 Technical Architecture, NC3TA Reference)	No data exchange (no physical connection)	Unstructured data exchange (free text)	Structured data exchange (manual handling i.e. email)	Seamless sharing of data (automated data sharing with common exchange model)	Seamless sharing of information (universal interpretation through cooperative data processing)
Taxonomy of Healthcare Interoperability (16)	Level 1: Non-electronic data (mail, telephone)	Level 2: Machine-transportable data (fax, .pdf	Level 3: Machine-organizable data (structured	Level 4: Machine-interpretable data – transmission of	

		files via email)	messages containing non-standardized data such as email free text, HL7 messages)	structured messages containing standardized and coded data)			
Centre for Information Technology Leadership, IT Maturity Model (18)	Level 1: Status-quo (non-electronic data)	Level 2: Fax-based data exchange	Level 3: Integration – machine organizable data such as email and e-messaging	Level 4: Interoperability – standardized interfaces and terminonologies			
Levels of Conceptual Interoperability Model (LCIM) (9)	Level 0: Stand alone systems (no interoperability)	Level 1: Technical Interoperability (infrastructure established	Level 2: Syntactic Interoperability (common structure to exchange information i.e. common data format or meta-standards	Level 3: Semantic Interoperability (meaning of data is shared, common systems approach)	Level 4: Pragmatic Interoperability (systems are aware of methods and procedures each system is using)	Level 5: Dynamic Interoperability (system understands changes in assumptions and constraints time)	Level 6: Conceptual Interoperability (assumptions and constraints are aligned & documented based on engineering methods to enable interpretation

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Expert Advisory Panel Process

Introduction

The Measuring Electronic Information Exchange (MEIE) research project is examining health system performance from the perspective of whether and how electronic information flows between providers in healthcare regions. Improving inter-provider information exchange, making it faster, more accurate, more secure, and allowing users to capture information from different sources, facilitates health system integration and care coordination.

The Expert Advisory Panel (EAP) will provide technical advice to the MEIE research project in its developmental stages as we select potential indicators, choose a pilot study domain and location, and formulate a survey instrument for the pilot study.

The EAP is purposefully composed of experts from the health care field (see attached contact list) with a range of perspectives and technical aptitudes to ensure a broad range of views are represented during the indicator selection and survey development process. Participants represent family health teams, public health units, hospitals, CCAC’s and government; they are from different provider disciplines such as physicians and administration, and have a range of perspectives and professions, from the clinical to the technical, and from service provision to policy-making.

Process

EAP members will be provided with a review of the literature (see attached) and parameters to guide indicator selection (See Appendix 1).

Participants are asked to review the material individually in advance of the October 26th meeting, and to consider their views on metrics which might be used to answer the question:

> **What metrics satisfy the indicator selection criteria (scientifically sound, relevant, feasible and communicable), and might contribute to our goal of measuring system integration using between-provider electronic health information exchange?**

A modified, iterated consensus rating procedure, called a nominal group technique, will be used to gather the EAP’s input. Following a general discussion:

- Each expert in turn will suggest a metric which they believe to be meaningful. The metrics will be recorded on a flip chart. This process will continue until the list of metrics is exhausted.

- An opportunity to clarify and discuss each metric will follow.

- Experts anonymously rank all suggested metrics using the selection parameters (Appendix 1). A 9-point Likert scale (see example attached) ranging from Strongly Disagree (1) to Strongly Agree (9) will be used for the ranking.

- The results will be collated in real time and results fed back to the panel. Mean scores and the degree of agreement amongst the panel will determine whether a metric is included in the next round of voting.

- The experts will have an opportunity to discuss the group rankings of indicators then modify the indicator list for a second round of ranking.

- In the second round of ranking, the experts re-rank the indicators which satisfied inclusion criteria from the first round.

Pre-determined criteria of agreement and disagreement between the experts' ratings will determine whether an indicator is included or rejected in both rounds: indicators where the mean falls in the 7-9 range, and there is agreement from over 70% of the experts will be included.

Results from the second round of voting and the content of the group discussion will be analyzed by the researchers, then presented and discussed in a follow up conference call. The expert panel will engage in a discussion about the feasibility of piloting data collection for the selected indicators in a healthcare region in Ontario.

The final metrics and the selected healthcare region will guide the development of a questionnaire for distribution to a target population early 2010. Experts' feedback on the questionnaire will be solicited pre and post testing.

Appendix 1.Metric/Indicator Selection Parameters

A previously conducted review of the literature (McMurray, 2007) provided a list of 74 indicator selection criteria which have been used in previous performance evaluation studies to guide the selection of indicators. They can be condensed into four categories; scientific soundness, relevance, feasibility and communicability.

Scientific soundness refers to such qualities as a criteria's evidence base, validity, reliability, theoretic foundation, specificity and objectivity. Validity and reliability are important characteristics of scientific soundness. Validity was more frequently cited over reliability. This result is at least intuitively reasonable, given that an indicator may be reliable, but if the measure is not valid, you may end up measuring the wrong thing correctly 100% of the time. **Relevance** refers to an indicator's meaning and usefulness.

The **feasibility** construct encompasses criteria such as data availability, data quality, data standards and ease of implementation. The final construct is increasingly recognized as important to the process of indicator selection (Pun & White, 2005) **Communicability** refers to such criteria as an indicator's clarity of proposed use, its definition, where appropriate its ability to be visually impactful and its simplicity in reporting. Understandability is commonly used as a parameter for indicator selection, perhaps representative of a growing sentiment that while substantive evidence is critical for an indicator to pass the 'acid test', unless it is understood by stakeholders it will not be used or supported (Mannion & Davies, 2002). The specific criteria for indicator evaluation in the MEIE study are:

Scientific Soundness:

1. Theory based(best), empirically based (second) or consensus based (third) but will consider experimental indicators (Pink et al., 2007)
2. Must be able to contribute to a summative evaluation of individual and organizational service providers in order create a system-level indicator of information exchange/system integration (Pink et al., 2007)
3. Evaluative rather than descriptive (Pink et al., 2007)
4. Uses benchmarks [preferred but unlikely in the MEIE study] (Pink et al., 2007)
5. Sensitive – so reflects change (Yasnoff et al., 2006)

Relevance:

6. Dimension for measurement must be electronic and involve shared clinical information/data (MEIE)
7. Reflective of the desired end state (Yasnoff et al., 2006)
8. Have the potential to be applied to health service providers in sectors across the continuum (Pink et al., 2007) i.e. hospitals, public health units, family health teams

9. Information/data must be capable of adding value to the care of a client or population (Pink et al., 2007)
10. Comprehensive - to reflect activities that impact most stakeholders and activities (Yasnoff et al., 2006)

Feasibility:

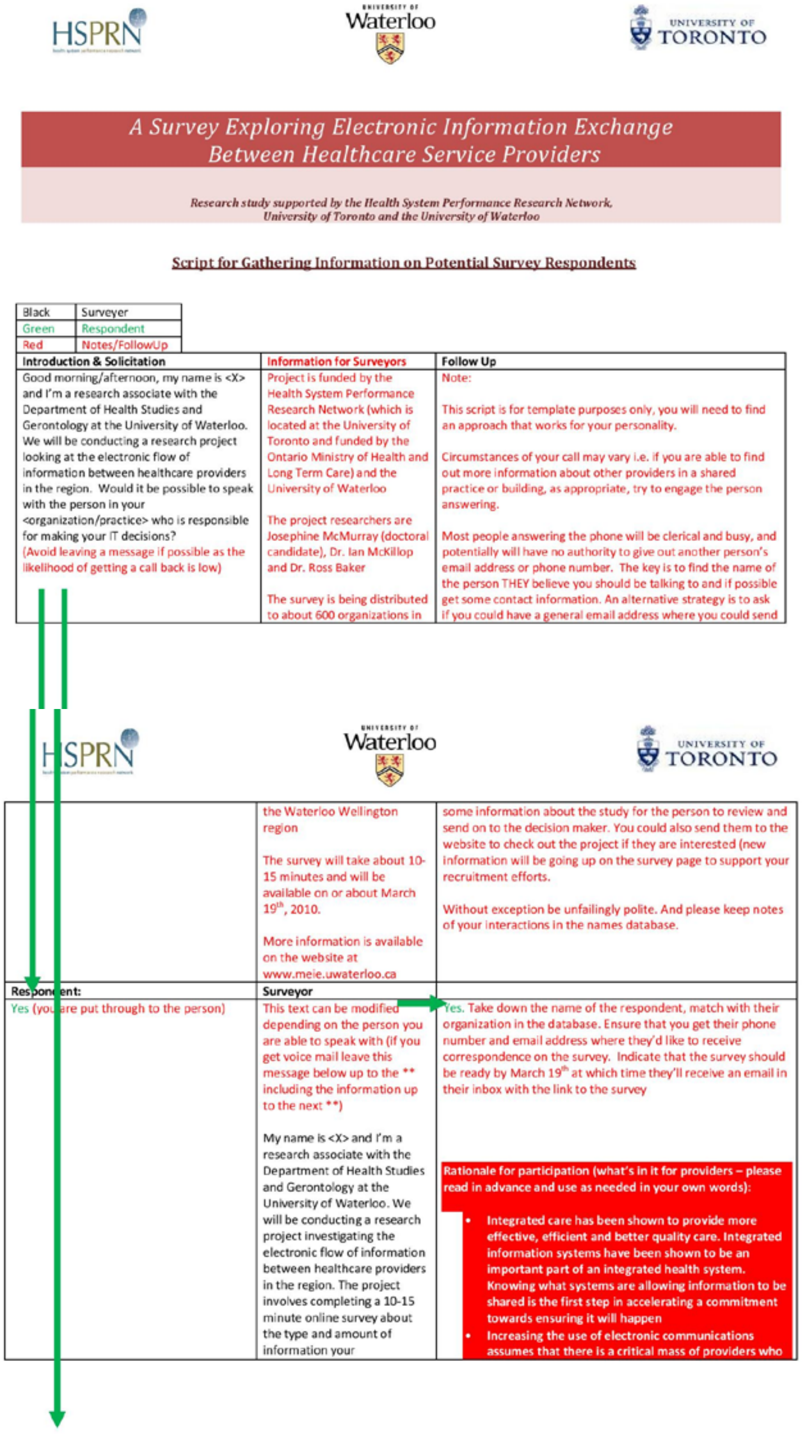
11. Easy to measure (Yasnoff et al., 2006)
12. Data is available (MEIE)

Communicability:

13. Capable of being understood by stakeholders (Mannion & Davies, 2002)
14. Meaningful to stakeholders (Yasnoff et al., 2006)

This list of criteria will be used to guide our choice of indicators i.e. an indicator should satisfy the criteria of scientific soundness, relevance, feasibility and communicability for it to be considered for inclusion in our study of regional electronic information exchange. Indicators may not satisfy all criteria, yet still be included in the study if there is compelling evidence that it will provide valuable insight in the flow of electronic inter-provider information exchange; in other words, the final criteria might be that of importance.

Appendix B. Participant Recruitment Phone Script



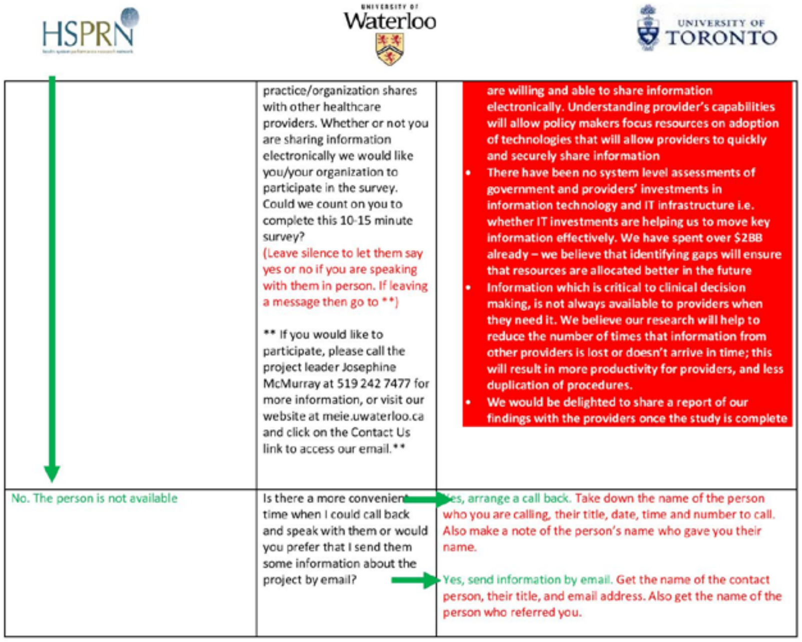
A Survey Exploring Electronic Information Exchange Between Healthcare Service Providers

Research study supported by the Health System Performance Research Network, University of Toronto and the University of Waterloo

Script for Gathering Information on Potential Survey Respondents

Black	Surveyer
Green	Respondent
Red	Notes/FollowUp

Introduction & Solicitation	**Information for Surveyors**	**Follow Up**
Good morning/afternoon, my name is <X> and I'm a research associate with the Department of Health Studies and Gerontology at the University of Waterloo. We will be conducting a research project looking at the electronic flow of information between healthcare providers in the region. Would it be possible to speak with the person in your <organization/practice> who is responsible for making your IT decisions? (Avoid leaving a message if possible as the likelihood of getting a call back is low)	Project is funded by the Health System Performance Research Network (which is located at the University of Toronto and funded by the Ontario Ministry of Health and Long Term Care) and the University of Waterloo The project researchers are Josephine McMurray (doctoral candidate), Dr. Ian McKillop and Dr. Ross Baker The survey is being distributed to about 600 organizations in the Waterloo Wellington region The survey will take about 10-15 minutes and will be available on or about March 19th, 2010. More information is available on the website at www.meie.uwaterloo.ca	Note: This script is for template purposes only, you will need to find an approach that works for your personality. Circumstances of your call may vary i.e. if you are able to find out more information about other providers in a shared practice or building, as appropriate, try to engage the person answering. Most people answering the phone will be clerical and busy, and potentially will have no authority to give out another person's email address or phone number. The key is to find the name of the person THEY believe you should be talking to and if possible get some contact information. An alternative strategy is to ask if you could have a general email address where you could send some information about the study for the person to review and send on to the decision maker. You could also send them to the website to check out the project if they are interested (new information will be going up on the survey page to support your recruitment efforts. Without exception be unfailingly polite. And please keep notes of your interactions in the names database.
Respondent:	**Surveyor**	
Yes (you are put through to the person)	This text can be modified depending on the person you are able to speak with (if you get voice mail leave this message below up to the ** including the information up to the next **) My name is <X> and I'm a research associate with the Department of Health Studies and Gerontology at the University of Waterloo. We will be conducting a research project investigating the electronic flow of information between healthcare providers in the region. The project involves completing a 10-15 minute online survey about the type and amount of information your	Yes. Take down the name of the respondent, match with their organization in the database. Ensure that you get their phone number and email address where they'd like to receive correspondence on the survey. Indicate that the survey should be ready by March 19th at which time they'll receive an email in their inbox with the link to the survey Rationale for participation (what's in it for providers – please read in advance and use as needed in your own words): • Integrated care has been shown to provide more effective, efficient and better quality care. Integrated information systems have been shown to be an important part of an integrated health system. Knowing what systems are allowing information to be shared is the first step in accelerating a commitment towards ensuring it will happen • Increasing the use of electronic communications assumes that there is a critical mass of providers who



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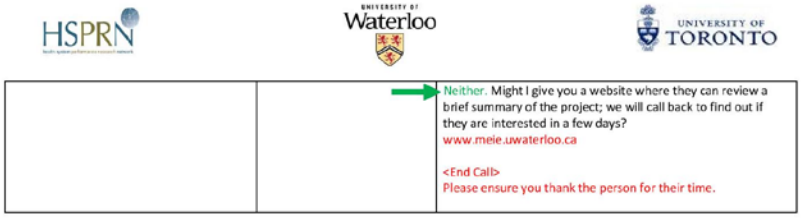
University of Waterloo
University of Toronto

	practice/organization shares with other healthcare providers. Whether or not you are sharing information electronically we would like you/your organization to participate in the survey. Could we count on you to complete this 10-15 minute survey? (Leave silence to let them say yes or no if you are speaking with them in person. If leaving a message then go to **) ** If you would like to participate, please call the project leader Josephine McMurray at 519 242 7477 for more information, or visit our website at meie.uwaterloo.ca and click on the Contact Us link to access our email.**	are willing and able to share information electronically. Understanding provider's capabilities will allow policy makers focus resources on adoption of technologies that will allow providers to quickly and securely share information • There have been no system level assessments of government and providers' investments in information technology and IT infrastructure i.e. whether IT investments are helping us to move key information effectively. We have spent over $2BB already – we believe that identifying gaps will ensure that resources are allocated better in the future • Information which is critical to clinical decision making, is not always available to providers when they need it. We believe our research will help to reduce the number of times that information from other providers is lost or doesn't arrive in time; this will result in more productivity for providers, and less duplication of procedures. • We would be delighted to share a report of our findings with the providers once the study is complete
No. The person is not available	Is there a more convenient time when I could call back and speak with them or would you prefer that I send them some information about the project by email?	Yes, arrange a call back. Take down the name of the person who you are calling, their title, date, time and number to call. Also make a note of the person's name who gave you their name. Yes, send information by email. Get the name of the contact person, their title, and email address. Also get the name of the person who referred you.



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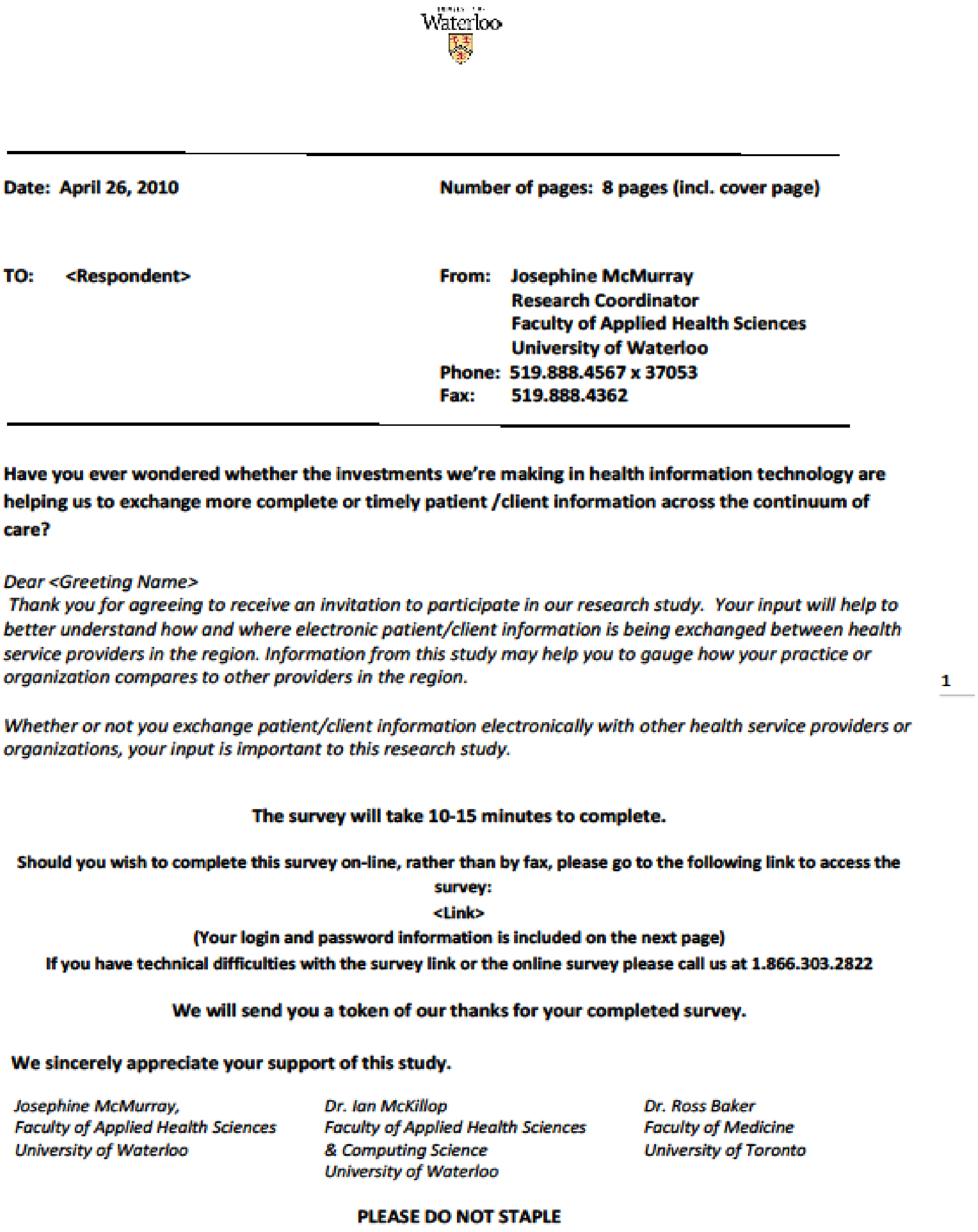
		Neither. Might I give you a website where they can review a brief summary of the project; we will call back to find out if they are interested in a few days? www.meie.uwaterloo.ca <End Call> Please ensure you thank the person for their time.

Appendix C. Questionnaire (Fax & Mail Version)



Waterloo

Date: April 26, 2010

Number of pages: 8 pages (incl. cover page)

TO: <Respondent>

From: Josephine McMurray
Research Coordinator
Faculty of Applied Health Sciences
University of Waterloo
Phone: 519.888.4567 x 37053
Fax: 519.888.4362

Have you ever wondered whether the investments we're making in health information technology are helping us to exchange more complete or timely patient /client information across the continuum of care?

Dear <Greeting Name>
Thank you for agreeing to receive an invitation to participate in our research study. Your input will help to better understand how and where electronic patient/client information is being exchanged between health service providers in the region. Information from this study may help you to gauge how your practice or organization compares to other providers in the region.

1

Whether or not you exchange patient/client information electronically with other health service providers or organizations, your input is important to this research study.

The survey will take 10-15 minutes to complete.

Should you wish to complete this survey on-line, rather than by fax, please go to the following link to access the survey:
<Link>
(Your login and password information is included on the next page)
If you have technical difficulties with the survey link or the online survey please call us at 1.866.303.2822

We will send you a token of our thanks for your completed survey.

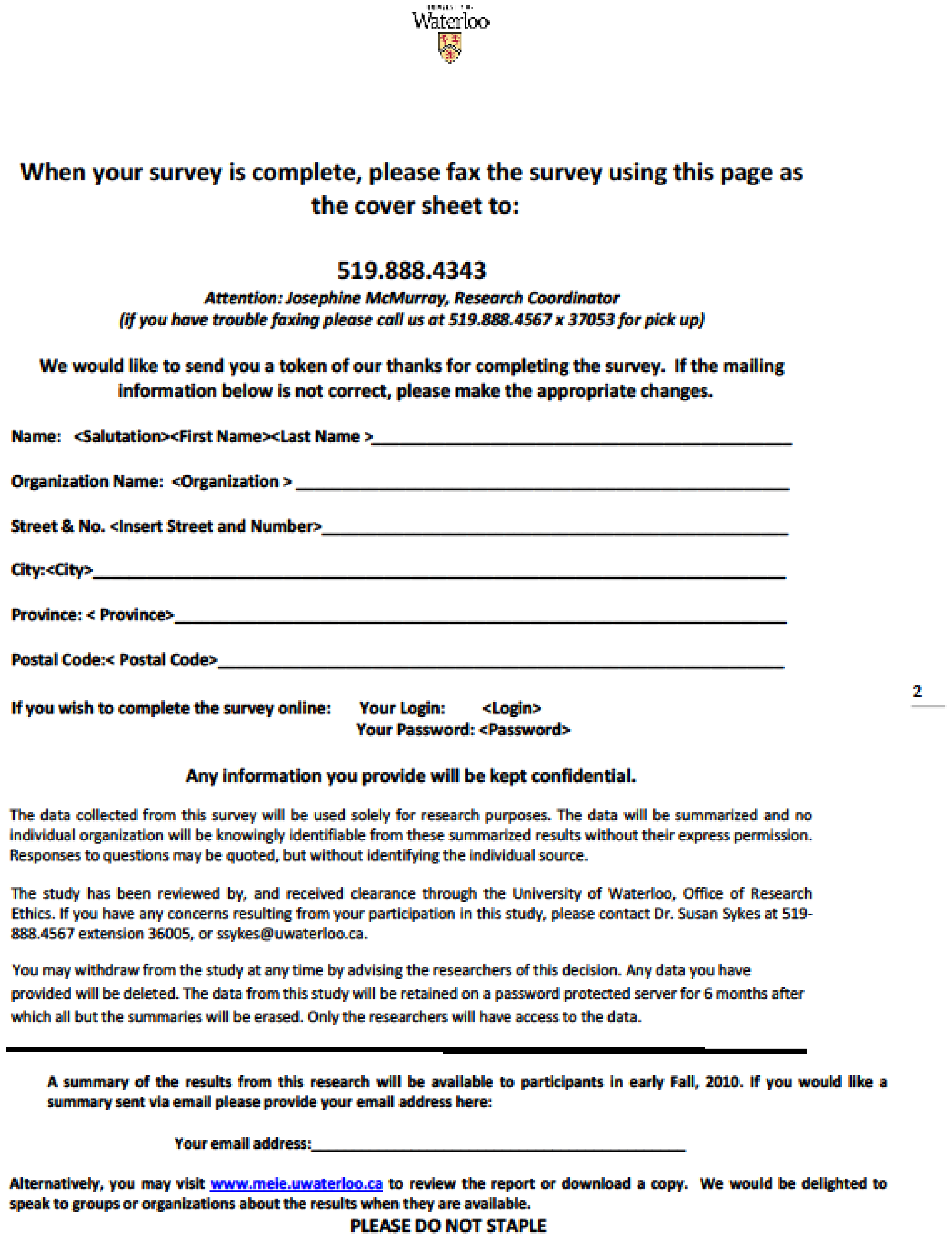
We sincerely appreciate your support of this study.

Josephine McMurray,
Faculty of Applied Health Sciences
University of Waterloo

Dr. Ian McKillop
Faculty of Applied Health Sciences
& Computing Science
University of Waterloo

Dr. Ross Baker
Faculty of Medicine
University of Toronto

PLEASE DO NOT STAPLE



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When your survey is complete, please fax the survey using this page as the cover sheet to:

519.888.4343

Attention: Josephine McMurray, Research Coordinator

(if you have trouble faxing please call us at 519.888.4567 x 37053 for pick up)

We would like to send you a token of our thanks for completing the survey. If the mailing information below is not correct, please make the appropriate changes.

Name: <Salutation><First Name><Last Name >____

Organization Name: <Organization > ____

Street & No. <Insert Street and Number>____

City:<City>____

Province: < Province>____

Postal Code:< Postal Code>____

If you wish to complete the survey online: Your Login: <Login>
Your Password: <Password>

2

Any information you provide will be kept confidential.

The data collected from this survey will be used solely for research purposes. The data will be summarized and no individual organization will be knowingly identifiable from these summarized results without their express permission. Responses to questions may be quoted, but without identifying the individual source.

The study has been reviewed by, and received clearance through the University of Waterloo, Office of Research Ethics. If you have any concerns resulting from your participation in this study, please contact Dr. Susan Sykes at 519-888.4567 extension 36005, or ssykes@uwaterloo.ca.

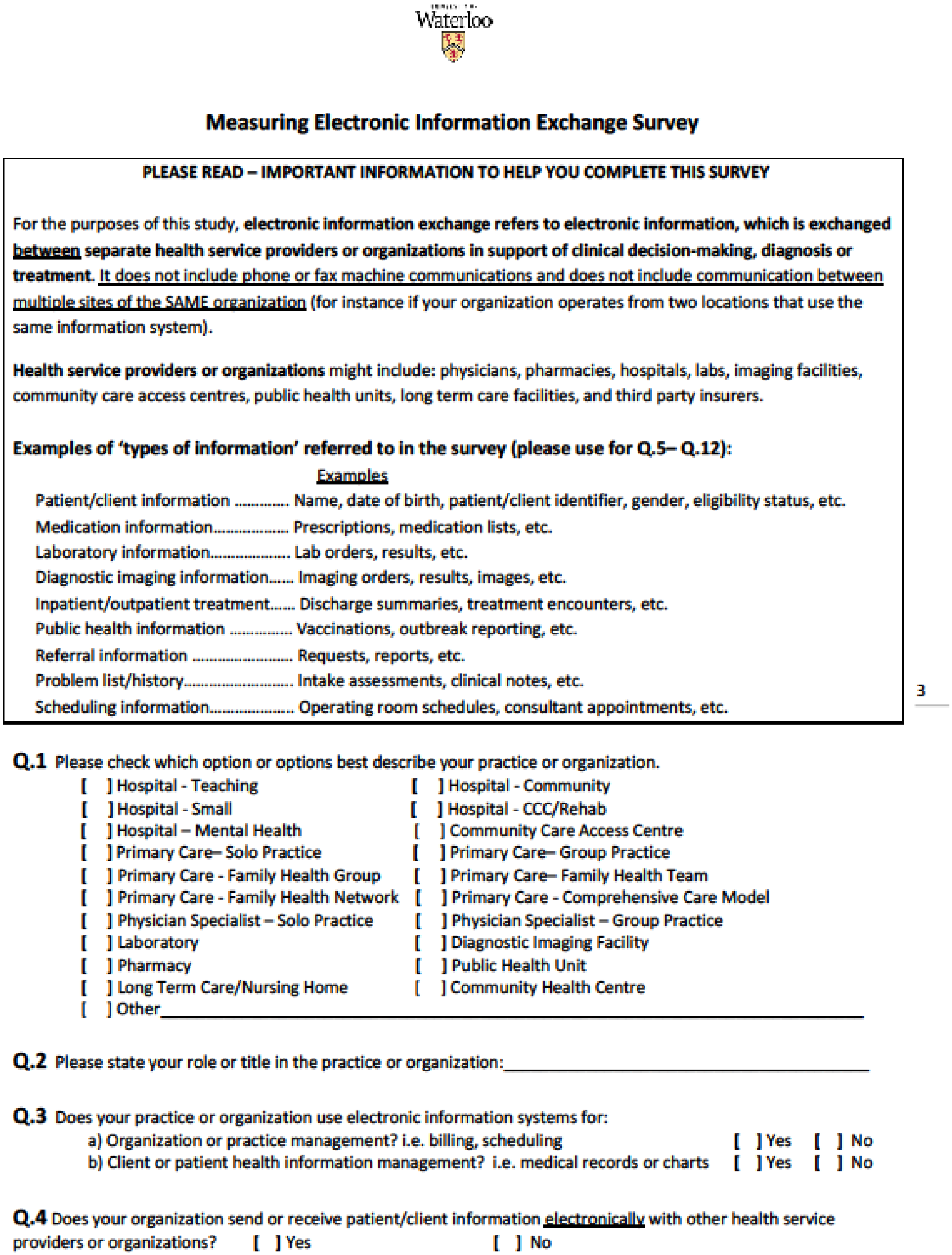
You may withdraw from the study at any time by advising the researchers of this decision. Any data you have provided will be deleted. The data from this study will be retained on a password protected server for 6 months after which all but the summaries will be erased. Only the researchers will have access to the data.

A summary of the results from this research will be available to participants in early Fall, 2010. If you would like a summary sent via email please provide your email address here:

Your email address:____

Alternatively, you may visit www.mele.uwaterloo.ca to review the report or download a copy. We would be delighted to speak to groups or organizations about the results when they are available.

PLEASE DO NOT STAPLE



Measuring Electronic Information Exchange Survey

PLEASE READ – IMPORTANT INFORMATION TO HELP YOU COMPLETE THIS SURVEY

For the purposes of this study, **electronic information exchange refers to electronic information, which is exchanged <u>between</u> separate health service providers or organizations in support of clinical decision-making, diagnosis or treatment**. <u>It does not include phone or fax machine communications and does not include communication between multiple sites of the SAME organization</u> (for instance if your organization operates from two locations that use the same information system).

Health service providers or organizations might include: physicians, pharmacies, hospitals, labs, imaging facilities, community care access centres, public health units, long term care facilities, and third party insurers.

Examples of 'types of information' referred to in the survey (please use for Q.5– Q.12):

	<u>Examples</u>
Patient/client information	Name, date of birth, patient/client identifier, gender, eligibility status, etc.
Medication information	Prescriptions, medication lists, etc.
Laboratory information	Lab orders, results, etc.
Diagnostic imaging information	Imaging orders, results, images, etc.
Inpatient/outpatient treatment	Discharge summaries, treatment encounters, etc.
Public health information	Vaccinations, outbreak reporting, etc.
Referral information	Requests, reports, etc.
Problem list/history	Intake assessments, clinical notes, etc.
Scheduling information	Operating room schedules, consultant appointments, etc.

Q.1 Please check which option or options best describe your practice or organization.

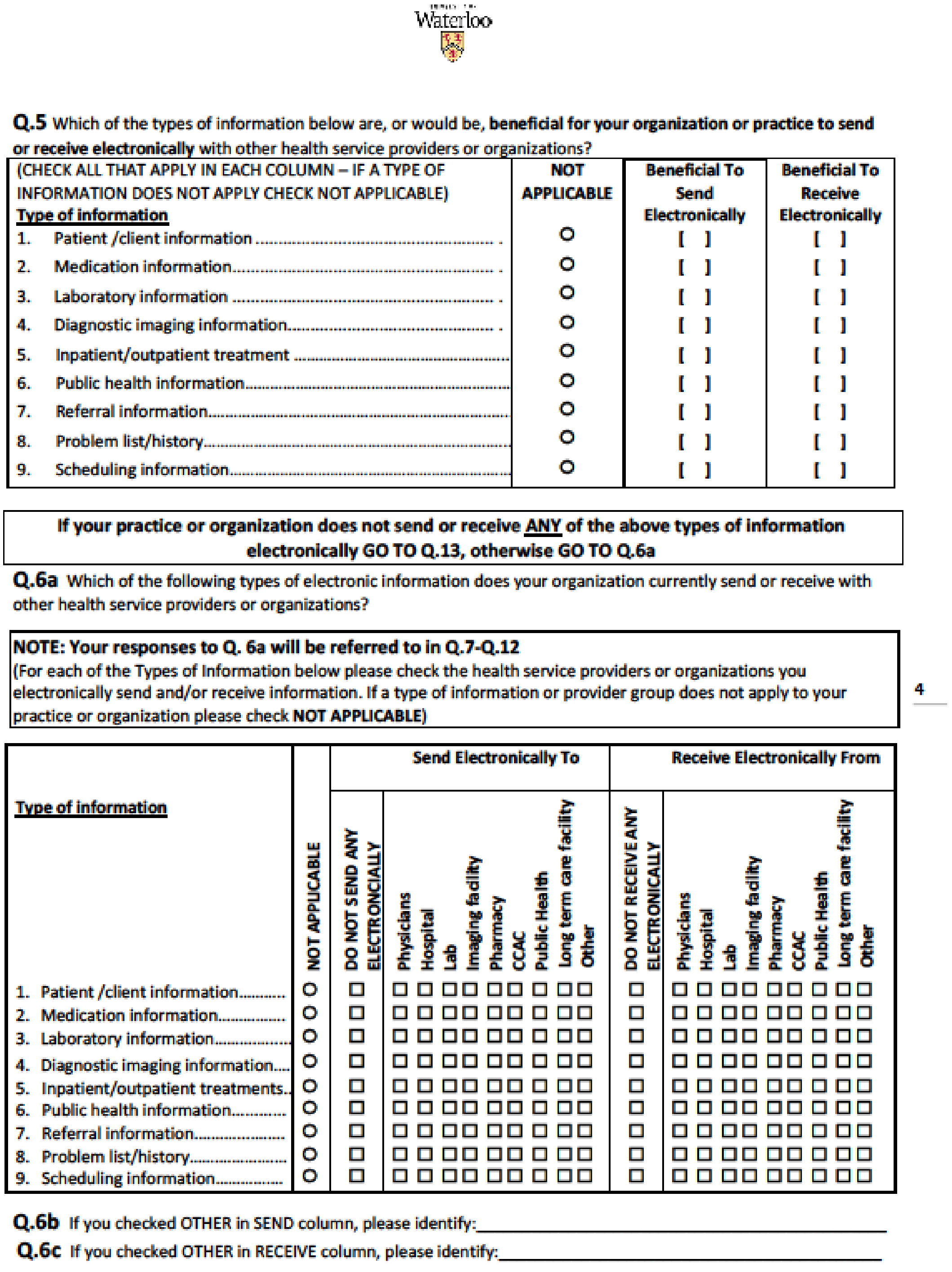
☐ Hospital - Teaching
☐ Hospital - Small
☐ Hospital – Mental Health
☐ Primary Care– Solo Practice
☐ Primary Care - Family Health Group
☐ Primary Care - Family Health Network
☐ Physician Specialist – Solo Practice
☐ Laboratory
☐ Pharmacy
☐ Long Term Care/Nursing Home
☐ Hospital - Community
☐ Hospital - CCC/Rehab
☐ Community Care Access Centre
☐ Primary Care– Group Practice
☐ Primary Care– Family Health Team
☐ Primary Care - Comprehensive Care Model
☐ Physician Specialist – Group Practice
☐ Diagnostic Imaging Facility
☐ Public Health Unit
☐ Community Health Centre
☐ Other____

Q.2 Please state your role or title in the practice or organization:________________________________

Q.3 Does your practice or organization use electronic information systems for:

a) Organization or practice management? i.e. billing, scheduling ☐ Yes ☐ No
b) Client or patient health information management? i.e. medical records or charts ☐ Yes ☐ No

Q.4 Does your organization send or receive patient/client information <u>electronically</u> with other health service providers or organizations? ☐ Yes ☐ No



Waterloo

Q.5 Which of the types of information below are, or would be, **beneficial for your organization or practice to send or receive electronically** with other health service providers or organizations?

(CHECK ALL THAT APPLY IN EACH COLUMN – IF A TYPE OF INFORMATION DOES NOT APPLY CHECK NOT APPLICABLE) **Type of information**	**NOT APPLICABLE**	**Beneficial To Send Electronically**	**Beneficial To Receive Electronically**
1. Patient /client information	○	[ ]	[ ]
2. Medication information	○	[ ]	[ ]
3. Laboratory information	○	[ ]	[ ]
4. Diagnostic imaging information	○	[ ]	[ ]
5. Inpatient/outpatient treatment	○	[ ]	[ ]
6. Public health information	○	[ ]	[ ]
7. Referral information	○	[ ]	[ ]
8. Problem list/history	○	[ ]	[ ]
9. Scheduling information	○	[ ]	[ ]

If your practice or organization does not send or receive ANY of the above types of information electronically GO TO Q.13, otherwise GO TO Q.6a

Q.6a Which of the following types of electronic information does your organization currently send or receive with other health service providers or organizations?

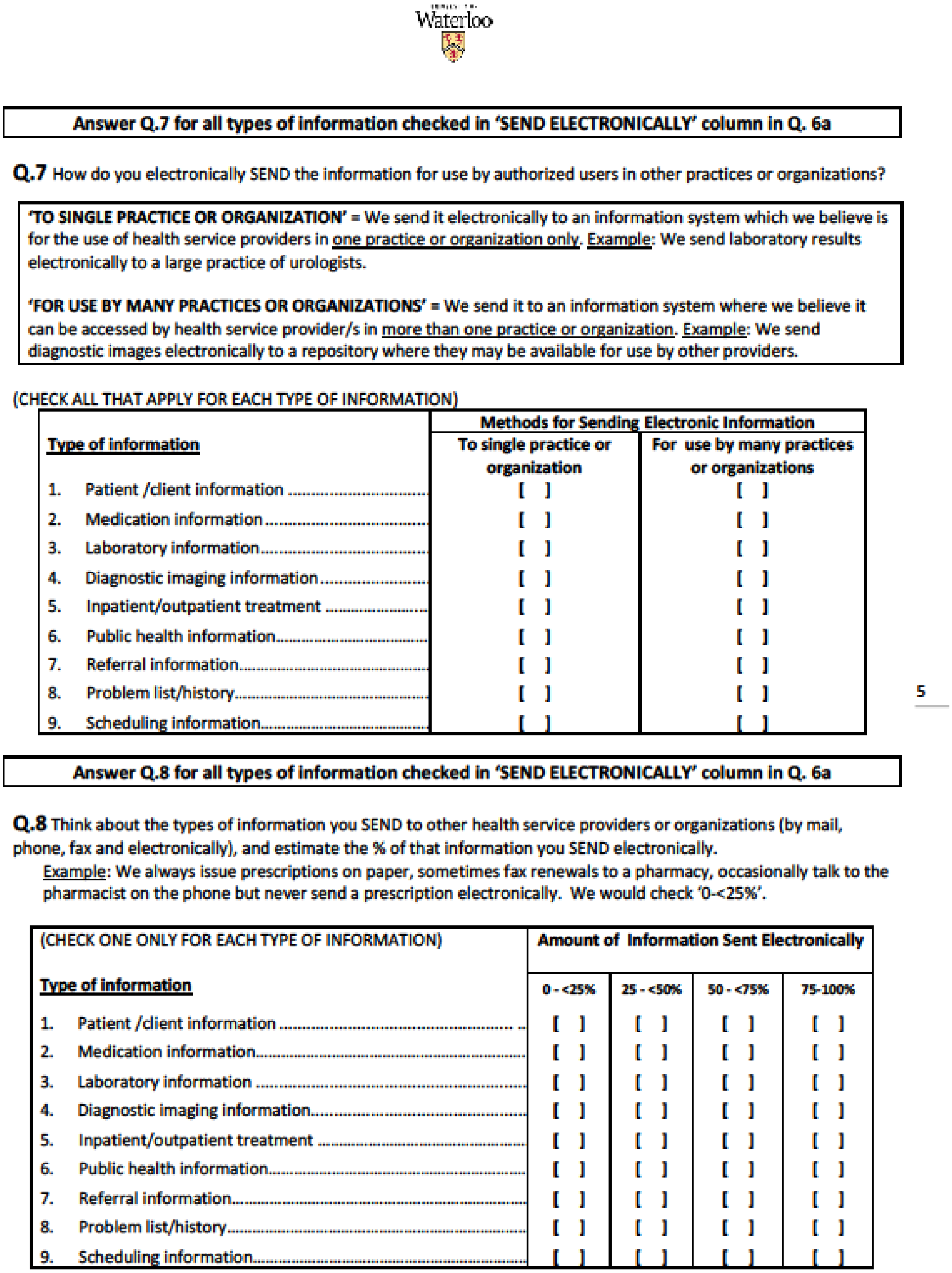
NOTE: Your responses to Q. 6a will be referred to in Q.7-Q.12
(For each of the Types of Information below please check the health service providers or organizations you electronically send and/or receive information. If a type of information or provider group does not apply to your practice or organization please check **NOT APPLICABLE**)

4

Type of information	**NOT APPLICABLE**	**Send Electronically To**										**Receive Electronically From**									
		DO NOT SEND ANY ELECTRONCIALLY	**Physicians**	**Hospital**	**Lab**	**Imaging facility**	**Pharmacy**	**CCAC**	**Public Health**	**Long term care facility**	**Other**	**DO NOT RECEIVE ANY ELECTRONICALLY**	**Physicians**	**Hospital**	**Lab**	**Imaging facility**	**Pharmacy**	**CCAC**	**Public Health**	**Long term care facility**	**Other**
1. Patient /client information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
2. Medication information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
3. Laboratory information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
4. Diagnostic imaging information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Inpatient/outpatient treatments	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Public health information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Referral information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Problem list/history	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
9. Scheduling information	○	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Q.6b If you checked OTHER in SEND column, please identify:____________________________________

Q.6c If you checked OTHER in RECEIVE column, please identify:____________________________________



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Answer Q.7 for all types of information checked in 'SEND ELECTRONICALLY' column in Q. 6a

Q.7 How do you electronically SEND the information for use by authorized users in other practices or organizations?

'TO SINGLE PRACTICE OR ORGANIZATION' = We send it electronically to an information system which we believe is for the use of health service providers in one practice or organization only. Example: We send laboratory results electronically to a large practice of urologists.

'FOR USE BY MANY PRACTICES OR ORGANIZATIONS' = We send it to an information system where we believe it can be accessed by health service provider/s in more than one practice or organization. Example: We send diagnostic images electronically to a repository where they may be available for use by other providers.

(CHECK ALL THAT APPLY FOR EACH TYPE OF INFORMATION)

Type of information	Methods for Sending Electronic Information: To single practice or organization	Methods for Sending Electronic Information: For use by many practices or organizations
1. Patient /client information	[ ]	[ ]
2. Medication information	[ ]	[ ]
3. Laboratory information	[ ]	[ ]
4. Diagnostic imaging information	[ ]	[ ]
5. Inpatient/outpatient treatment	[ ]	[ ]
6. Public health information	[ ]	[ ]
7. Referral information	[ ]	[ ]
8. Problem list/history	[ ]	[ ]
9. Scheduling information	[ ]	[ ]

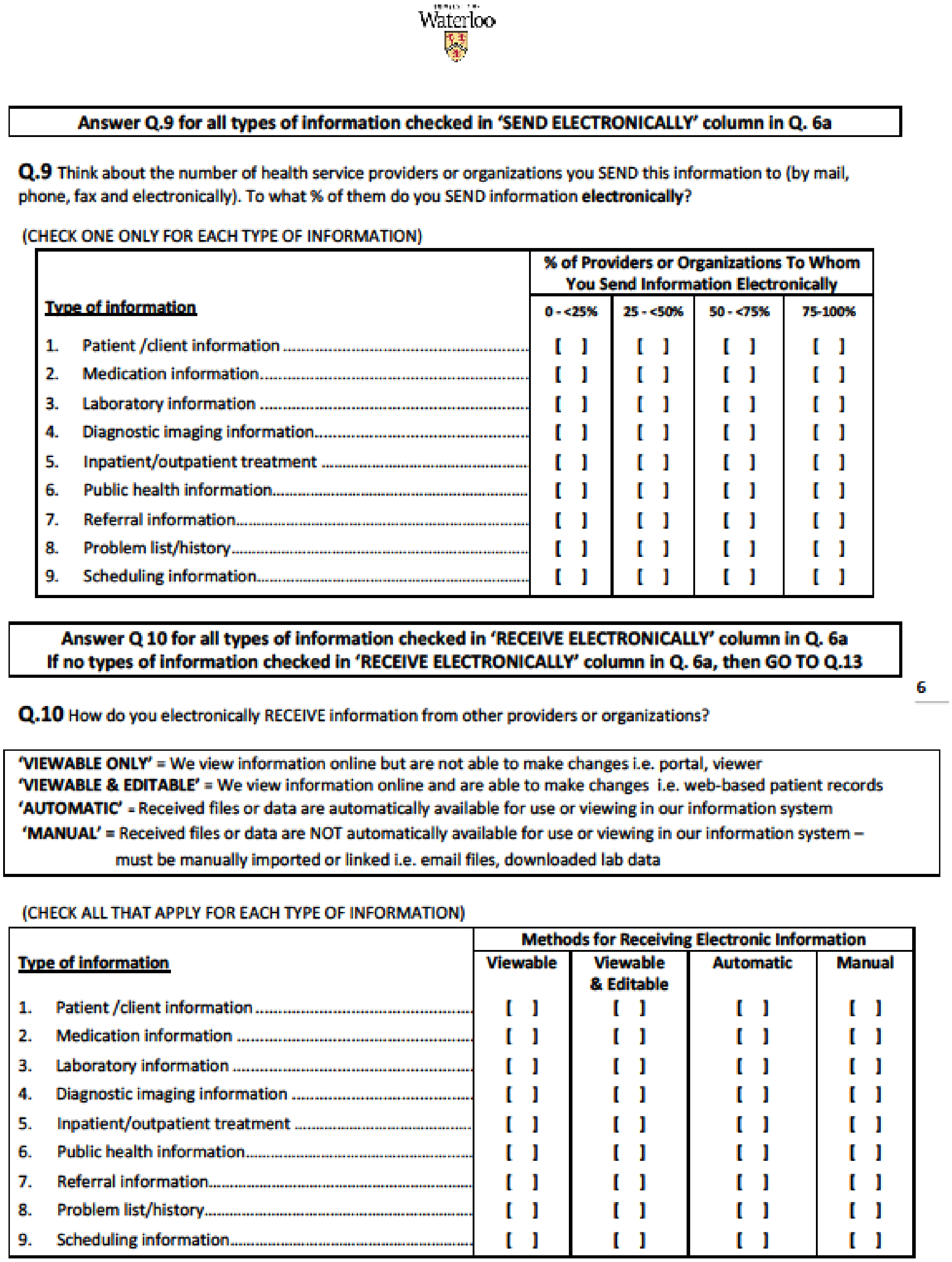
Answer Q.8 for all types of information checked in 'SEND ELECTRONICALLY' column in Q. 6a

Q.8 Think about the types of information you SEND to other health service providers or organizations (by mail, phone, fax and electronically), and estimate the % of that information you SEND electronically.

Example: We always issue prescriptions on paper, sometimes fax renewals to a pharmacy, occasionally talk to the pharmacist on the phone but never send a prescription electronically. We would check '0-<25%'.

(CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

Type of information	Amount of Information Sent Electronically: 0 - <25%	25 - <50%	50 - <75%	75-100%
1. Patient /client information	[ ]	[ ]	[ ]	[ ]
2. Medication information	[ ]	[ ]	[ ]	[ ]
3. Laboratory information	[ ]	[ ]	[ ]	[ ]
4. Diagnostic imaging information	[ ]	[ ]	[ ]	[ ]
5. Inpatient/outpatient treatment	[ ]	[ ]	[ ]	[ ]
6. Public health information	[ ]	[ ]	[ ]	[ ]
7. Referral information	[ ]	[ ]	[ ]	[ ]
8. Problem list/history	[ ]	[ ]	[ ]	[ ]
9. Scheduling information	[ ]	[ ]	[ ]	[ ]



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Answer Q.9 for all types of information checked in 'SEND ELECTRONICALLY' column in Q. 6a

Q.9 Think about the number of health service providers or organizations you SEND this information to (by mail, phone, fax and electronically). To what % of them do you SEND information **electronically**?

(CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

Type of information	**% of Providers or Organizations To Whom You Send Information Electronically**			
	0 - <25%	**25 - <50%**	**50 - <75%**	**75-100%**
1. Patient /client information	☐	☐	☐	☐
2. Medication information	☐	☐	☐	☐
3. Laboratory information	☐	☐	☐	☐
4. Diagnostic imaging information	☐	☐	☐	☐
5. Inpatient/outpatient treatment	☐	☐	☐	☐
6. Public health information	☐	☐	☐	☐
7. Referral information	☐	☐	☐	☐
8. Problem list/history	☐	☐	☐	☐
9. Scheduling information	☐	☐	☐	☐

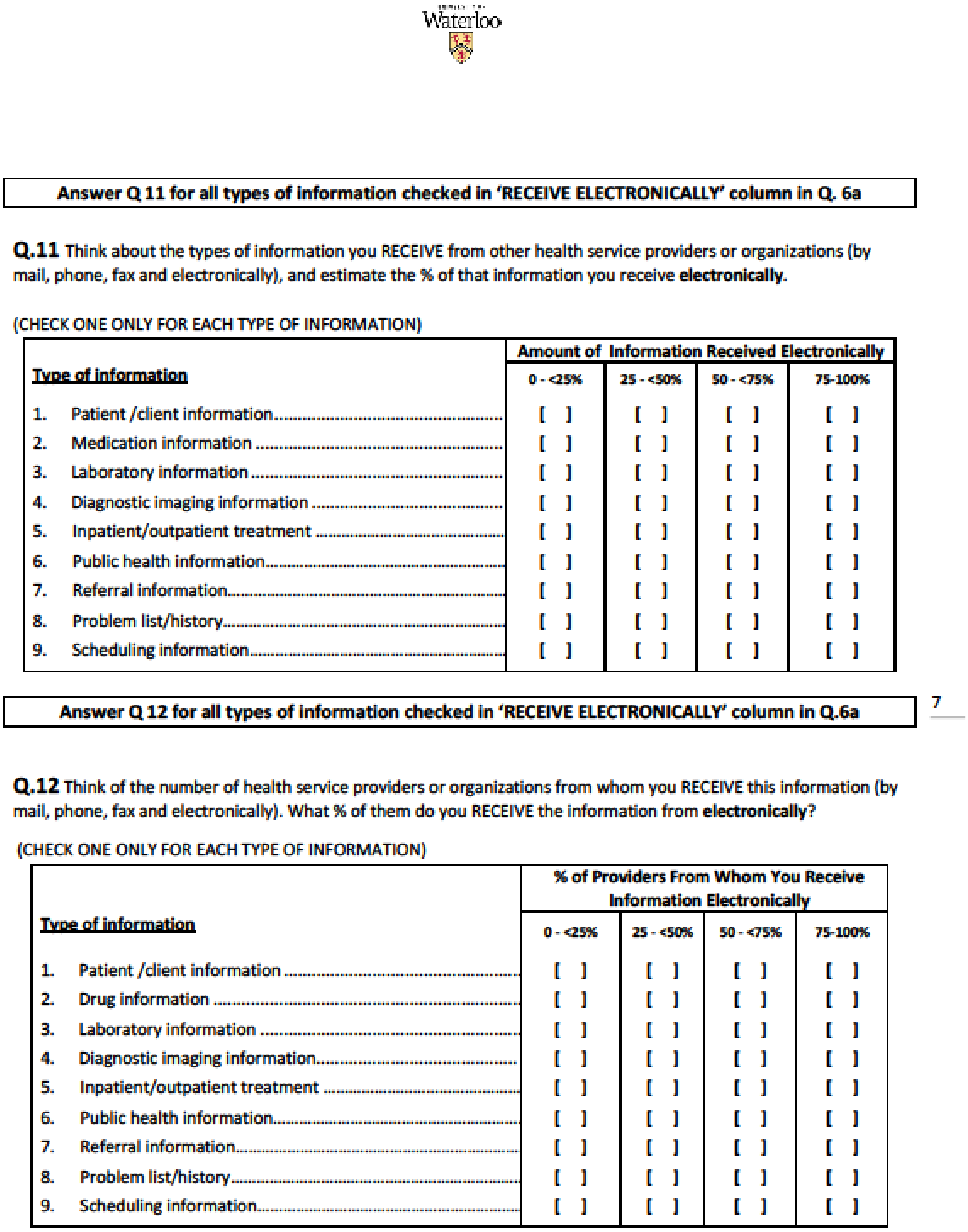
Answer Q 10 for all types of information checked in 'RECEIVE ELECTRONICALLY' column in Q. 6a
If no types of information checked in 'RECEIVE ELECTRONICALLY' column in Q. 6a, then GO TO Q.13

Q.10 How do you electronically RECEIVE information from other providers or organizations?

'VIEWABLE ONLY' = We view information online but are not able to make changes i.e. portal, viewer
'VIEWABLE & EDITABLE' = We view information online and are able to make changes i.e. web-based patient records
'AUTOMATIC' = Received files or data are automatically available for use or viewing in our information system
'MANUAL' = Received files or data are NOT automatically available for use or viewing in our information system – must be manually imported or linked i.e. email files, downloaded lab data

(CHECK ALL THAT APPLY FOR EACH TYPE OF INFORMATION)

Type of information	**Methods for Receiving Electronic Information**			
	Viewable	**Viewable & Editable**	**Automatic**	**Manual**
1. Patient /client information	☐	☐	☐	☐
2. Medication information	☐	☐	☐	☐
3. Laboratory information	☐	☐	☐	☐
4. Diagnostic imaging information	☐	☐	☐	☐
5. Inpatient/outpatient treatment	☐	☐	☐	☐
6. Public health information	☐	☐	☐	☐
7. Referral information	☐	☐	☐	☐
8. Problem list/history	☐	☐	☐	☐
9. Scheduling information	☐	☐	☐	☐



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Answer Q 11 for all types of information checked in 'RECEIVE ELECTRONICALLY' column in Q. 6a

Q.11 Think about the types of information you RECEIVE from other health service providers or organizations (by mail, phone, fax and electronically), and estimate the % of that information you receive **electronically**.

(CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

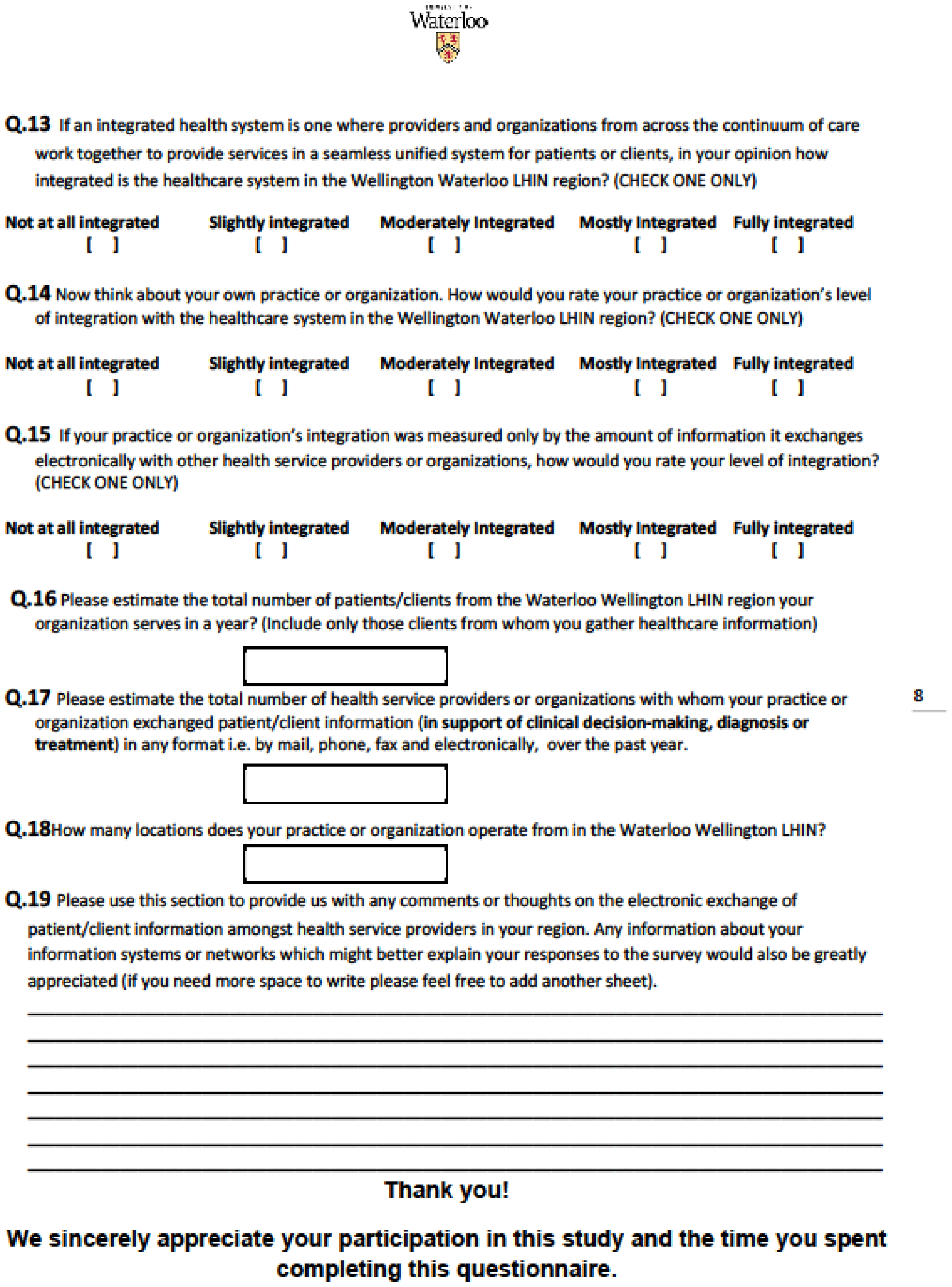
Type of information	**Amount of Information Received Electronically**			
	0 - <25%	**25 - <50%**	**50 - <75%**	**75-100%**
1. Patient /client information	☐	☐	☐	☐
2. Medication information	☐	☐	☐	☐
3. Laboratory information	☐	☐	☐	☐
4. Diagnostic imaging information	☐	☐	☐	☐
5. Inpatient/outpatient treatment	☐	☐	☐	☐
6. Public health information	☐	☐	☐	☐
7. Referral information	☐	☐	☐	☐
8. Problem list/history	☐	☐	☐	☐
9. Scheduling information	☐	☐	☐	☐

Answer Q 12 for all types of information checked in 'RECEIVE ELECTRONICALLY' column in Q.6a

Q.12 Think of the number of health service providers or organizations from whom you RECEIVE this information (by mail, phone, fax and electronically). What % of them do you RECEIVE the information from **electronically**?

(CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

Type of information	**% of Providers From Whom You Receive Information Electronically**			
	0 - <25%	**25 - <50%**	**50 - <75%**	**75-100%**
1. Patient /client information	☐	☐	☐	☐
2. Drug information	☐	☐	☐	☐
3. Laboratory information	☐	☐	☐	☐
4. Diagnostic imaging information	☐	☐	☐	☐
5. Inpatient/outpatient treatment	☐	☐	☐	☐
6. Public health information	☐	☐	☐	☐
7. Referral information	☐	☐	☐	☐
8. Problem list/history	☐	☐	☐	☐
9. Scheduling information	☐	☐	☐	☐



Q.13 If an integrated health system is one where providers and organizations from across the continuum of care work together to provide services in a seamless unified system for patients or clients, in your opinion how integrated is the healthcare system in the Wellington Waterloo LHIN region? (CHECK ONE ONLY)

Not at all integrated	Slightly integrated	Moderately Integrated	Mostly Integrated	Fully integrated
[ ]	[ ]	[ ]	[ ]	[ ]

Q.14 Now think about your own practice or organization. How would you rate your practice or organization's level of integration with the healthcare system in the Wellington Waterloo LHIN region? (CHECK ONE ONLY)

Not at all integrated	Slightly integrated	Moderately Integrated	Mostly Integrated	Fully integrated
[ ]	[ ]	[ ]	[ ]	[ ]

Q.15 If your practice or organization's integration was measured only by the amount of information it exchanges electronically with other health service providers or organizations, how would you rate your level of integration? (CHECK ONE ONLY)

Not at all integrated	Slightly integrated	Moderately Integrated	Mostly Integrated	Fully integrated
[ ]	[ ]	[ ]	[ ]	[ ]

Q.16 Please estimate the total number of patients/clients from the Waterloo Wellington LHIN region your organization serves in a year? (Include only those clients from whom you gather healthcare information)

Q.17 Please estimate the total number of health service providers or organizations with whom your practice or organization exchanged patient/client information (**in support of clinical decision-making, diagnosis or treatment**) in any format i.e. by mail, phone, fax and electronically, over the past year.

8

Q.18 How many locations does your practice or organization operate from in the Waterloo Wellington LHIN?

Q.19 Please use this section to provide us with any comments or thoughts on the electronic exchange of patient/client information amongst health service providers in your region. Any information about your information systems or networks which might better explain your responses to the survey would also be greatly appreciated (if you need more space to write please feel free to add another sheet).

Thank you!

We sincerely appreciate your participation in this study and the time you spent completing this questionnaire.

Appendix D. Application for Ethics Review for Consensus Development Process

ORE OFFICE USE ONLY

ORE #_______________

Please remember to PRINT AND SIGN the form, and forward TWO copies to the Office of Research Ethics, Needles Hall, Room 1024, with all attachments.

A. GENERAL INFORMATION

1. Title of Project: Measuring Electronic Information Exchange

2. a) Principal and Co-Investigator(s)

Name	Department	Ext:	e-mail:
Ian McKillop (faculty)	Health Studies & GerontologySchool of Computer Science	37127	ian@uwaterloo.ca

2. b) Collaborator(s)

Name	Department	Ext:	e-mail:
Ross Baker	HPME, University of Toronto		ross.baker@utoronto.ca

3. Faculty Supervisor(s)

Name	Department	Ext:	e-mail:

4. Student Investigator(s)

Name	Department	Ext:	e-mail:	Local Phone #:
Josephine McMurray	Health Studies & Gerontology	37053	djbmcmur@uwaterloo.ca	519 242 7477
Tim Chin	Recreation & Leisure Studies	84620	wtchin@uwaterloo.ca	519 502 3675
Emily Piraino	Health Studies & Gerontology	N/a	piraino.emily@gmail.com	

5. Level of Project: Faculty Research **Specify Course:**

Research Project/Course Status: New Project\Course

6. Funding Status (if there is an industry sponsor and procedures pose greater than minimal risk, then Appendix B is to be completed):

Is this project currently funded? Yes

- If Yes, provide Name of Sponsor and include the title of the grant/contract: : Health System Performance Research Network

- If No, is funding being sought OR if Yes, is additional funding being sought? No
- Period of Funding: September 1, 2009 - March 31, 2010

7. Does this research involve another institution or site? Yes
If Yes, what other institutions or sites are involved:
University of Toronto

8. Has this proposal been, or will it be, submitted to any other Research Ethics Board/Institutional Review Board? No

9. For Undergraduate and Graduate Research:

Has this proposal received approval of a Department Committee? Not Dept. Req.

10. a) Indicate the anticipated commencement date for this project: 10/26/2009

b) Indicate the anticipated completion date for this project: 8/31/2010

B. SUMMARY OF PROPOSED RESEARCH

1. Purpose and Rationale for Proposed Research

a. Describe the purpose (objectives) and rationale of the proposed project and include any hypothesis(es)/research questions to be investigated. For a clinical trial/medical device testing summarize the research proposal using the following headings: Purpose, Hypothesis, Justification, and Objectives. Where available, provide a copy of a research proposal. For a clinical trial/medical device testing a research proposal is required:
Electronic Information Exchange as a Key Enabler of Improved Care
Integrated health systems "consist of multiple partners, operate along numerous dimensions and at various levels of intensity, and encompass a variety of components, structures, and designs" (Marquart & Konrad, 1996). Information systems in particular can more efficiently and effectively link this patchwork of partners across the continuum of care (Shortell, Gillies, & Anderson, 1994), so they are better positioned to "deliver services that people need, now and in the future".
We know participants should exchange critical information yet the process has been hobbled by the health system's notable fragmentation and complexity (Halamka et al., 2005),

divisions created by professional doctrine and practice, structural and political disparities (Pink, Guerriere, & Leatt, 2000) and a reliance on paper-based systems; as a result, despite economic and quality control imperatives, the process of building information infrastructure and its corollary system integration, has been slow and complicated. Not surprisingly therefore, coordination of care continue to be hampered by the lack of shared and timely patient information (Eckman, Bennett, Kaufman, & Tenner, 2007).

There's no lack of clinical data or information in the healthcare system; however much of the information resides in silos which are inaccessible to other participants in the system (i.e. hospital data is not available to other care providers, patient-generated information such as treatment compliance is not available to care providers, diagnostic results are not available to patients). It is at the organizational interface where diminished care coordination capacity puts a patient at risk and where bottlenecks which affect the efficiency of a system as a whole are most likely to occur (Hofmarcher, Oxley, & Rusticelli, 2007).

Health system integration exists on a continuum according to Konrad (1996), with information sharing and communication between participants at the lowest level and the creation of a single authority with, comprehensive management and governance at the highest level. Ontario's regional coordinating entities, Local Health Integration Networks, were introduced in 2006 to, amongst other goals, "achieve an integrated health system". Partnerships to effect local organizational integration and a seamless continuum of care have been enacted in some regions in contrast to much of the previous investment in healthcare information technology which had been directed to creating local electronic databases and an infrastructure for data storage. The new focus is on making relevant data accessible to all health system participants. In fact, it has become a national strategic imperative; integrating information from various parts of the health system, such as long term care, palliative care, hospitals, pharmacies, public health and doctors' offices, is the goal of the pan-Canadian inter-operable health record through Canada's Health Infoway (Giokas, 2009).

Understanding Information Flow Will Guide Policy & Resource Allocation

Improving inter-organizational information exchange, making it faster, more accurate, more secure, and allowing users to capture information from different sources, should facilitate integration and care coordination (Pink et al., 2000) with consequent improvement in quality and reduced duration of care (Stiel et al., 2003; van Walraven et al., 2008), increased accessibility (Durbin et al., 2001),cost reduction from fewer redundant medical procedures, reduced patient transfers (Hodge, 2008), and improvements to medical error rates (Schabetsberger et al., 2006).

The importance of information and communication technology in moving data through a system (Walker et al., 2005) suggests that technology adoption to facilitate inter-organizational exchange of information or data across a health system could provide a measure of system integration. As there are currently no recognized indicators to measure the integration of information flows at the system level, decision makers and those responsible for developing policy are unable to both measure their progress towards this goal, nor to appraise the value of current and future IT investments to support the initiative. Measuring the intensity of inter-organizational electronically shared data will provide a measure of health information system integration. In combination with other system data already available and that collected as part of this research project, future analysis of the metric has the potential to provide insight into all three of the integration components identified by Devers et. al (1994); these being clinical integration, physician-system integration and functional integration by helping to inform questions such as how integration is impacting outcomes such as alternate level of care bed occupancy in hospitals and emergency room wait times.

Research Approach & Future Opportunities
Our interest is in developing a rigorous methodological approach to capture, quantify and measure the capacity to move information across a health system. The short turnaround time for results calls for a research design which uses a representative sample rather than an entire system population. For convenience, therefore, one geographic area defined by the current Ontario Local Health Integration governance structure will be selected, and participants will be selected from across the continuum of care. A preliminary methodology has been conceived however, the final research approach remains flexible at this time, and will be finalized following the literature review and consultations with experts and key stakeholders.
Health services exist in a geographic context and Canadian healthcare organizations are beginning to harness this information for analysis and planning . Geospatial data have been used to develop indicators in healthcare, but the main focus has been on epidemiological and public health monitoring, and demand or facility management (McLafferty, 2003). We will use mapping applications to analyze & visualize electronic information flows and contribute a novel perspective of structural health system integration.

b. In lay language, provide a one paragraph (approximately 100 words) summary of the project including purpose, the anticipated potential benefits, and basic procedures used.
This research will investigate metrics which measure health system integration by the flow of electronic information between healthcare providers. A pilot test will determine the scientific soundness, feasibility, relevance and communicability of the derived metric through a pilot study and post-pilot consultations with stakeholders.

C. DETAILS OF STUDY

1. Methodology/Procedures

a. Indicate all of the procedures that will be used. Append to form 101 a copy of all materials to be used in this study.

Interview(s) (in person)
Audio-recording

b. Provide a detailed, sequential description of the procedures to be used in this study. For studies involving multiple procedures or sessions, provide a flow chart. Where applicable, this section also should give the research design (e.g., cross-over design, repeated measures design).
Stage 1. A modified, iterated consensus rating procedure, called a nominal group technique, will be used to gather an Expert Panel’s input. A two-round process will be conducted at a half day workshop to which the experts will be invited. Following a general discussion, each expert in turn will suggest a metric of their choosing which they believe to be meaningful. The metrics will be recorded on a flip chart, and briefly discussed by the group. This process will continue until the list of metrics is exhausted or as time allows.

Experts will anonymously rank all suggested metrics using the selection parameters (below). A 9-point Likert scale (see example attached) ranging from Disagree (1) to Agree (9) will be used for the ranking. The results will be collated in real time and fed back to the panel. Mean scores and the degree of agreement amongst the panel will determine whether a metric is included in the next round of voting. Results of the first round of voting will be fed back to the experts; they will them be provided with a chance to comment on the group ranked indicators, and to modify the indicators for the second round of ranking. In the second round of ranking, the experts rerank the indicators which satisfied inclusion criteria from the first round. Pre-determined criteria of agreement and disagreement between the experts' ratings will determine whether an indicator is included or rejected in both rounds. Indicators where the mean falls in the 7-9 range, and there is agreement from over 70% of the experts will be included.

Results from the second round of voting will be analyzed by the researchers, then presented and discussed in a follow up conference call. The expert panel will engage in a discussion about the feasibility of piloting data collection for the selected indicators in a healthcare region in Ontario. See attached Stage 1 research design flow chart.

Stage 2.: Methods are to be determined, but it is anticipated that an online, self-reported survey will be used to gather data for the Pilot Study. An amendment to this research application will be submitted once the methodology,sample and tools are finalized.

c. Will this study involve the administration/use of any drug, medical device, biologic, or natural health product? No

2. Participants Involved in the Study

a. Indicate who will be recruited as potential participants in this study.
Non-UW Participants:
Adults

b. Describe the potential participants in this study including group affiliation, gender, age range and any other special characteristics. Describe distinct or common characteristics of the potential participants or a group (e.g., a group with a particular health condition) that are relevant to recruitment and/or procedures (e.g., A group with asbestosis is included. People with this condition tend to be male, 50+ years, worked with asbestos.). If only one gender is to be selected for recruitment, provide a justification for this.

Stage 1 (Nominal Group Technique – "Expert Panels". Participants will be drawn from the service provider, funding and policy-making communities. Experts will have a recognized expertise in their health domain, professional acumen and skills or interest in issues related to the electronic exchange of health information. Representatives from the following domains might be included: acute care hospitals, CCACs, primary care, Ministry of Health and Long Term Care, eHealth Ontario and Local Health Integration Networks (LHINs). Experts will be asked to sign a Consent to Participate form.

Stage 2. Participants are as yet to be determined. A decision on the location for the Stage 2. Pilot Study will be made following our expert panel meeting on October 26th. A Revision to this ORE Form 101 will be submitted once the sample population is identified and survey instrument developed.

c. How many participants are expected to be involved in this study? For a clinical trial, medical device testing, or study with procedures that pose greater than minimal risk, sample size determination information is to be provided, as outlined in Guidance Note C2c.

Under 15 people are expect to be involved in Stage 1 of the study; there is no known risk to participants.

3. Recruitment Process and Study Location

a. From what source(s) will the potential participants be recruited?
Healthcare settings, nursing homes etc.
LHIN, MOHLTC

b. Describe how and by whom the potential participants will be recruited. Provide a copy of any materials to be used for recruitment (e.g. posters(s), flyers, cards, advertisement(s), letter(s), telephone, email, and other verbal scripts).
Expert participants are, for the most part, expected to be known to the researchers. In which case, phone calls and email will be used for recruitment. The script would loosely resemble the following: The research project is funded by the Health System Performance Research Network (HSPRN) http://hsprn.ca/). The HSPRN research mandate is to explore innovative and scientifically novel approaches to measuring health system performance in Ontario. We are examining whether and how electronic information flows between providers in healthcare regions. Improving inter-provider information exchange, making it faster, more accurate, more secure, and allowing users to capture information from different sources, will facilitate health system integration and care coordination; our goal is to develop a system level indicator which measures that integration, examining the amount of information exchange between those who are delivering healthcare. We are in the process of completing a literature review to find metrics which have been used to measure information flow/exchange. Subsequently, we intend to convene an expert panel to review those indicators to determine whether and how they can be measured. Our project includes funding for pilot/field testing. We would be most interested in having you participate on our expert panel. I anticipate that our expert panel will consist of 8-12 people, a mix of government, local providers and researchers. I am in the process of recruiting other participants. Depending on availability, our first half day meeting will be here in Waterloo, and we anticipate two follow up one-hour follow up conference calls. Would you be prepared to participate? Thanks so much for your assistance.

c. Where will the study take place? On campus: University Club, teleconference

4. Remuneration for Participants
Will participants receive remuneration (financial, in-kind, or otherwise) for participation? Yes
If Yes, provide details:

Stage 1. Participant transportation expenses to and from the University will be covered by the research project. A small appreciation gift (under $20) will be given to the experts to thank them for their participation.

5. Feedback to Participants

Describe the plans for provision of study feedback and attach a copy of the feedback letter to be used. Wherever possible, written feedback should be provided to study participants including a statement of appreciation, details about the purpose and predictions of the study, restatement of the provisions for confidentiality and security of data, an indication of when a study report will be available and how to obtain a copy, contact information for the researchers, and the ethics review and clearance statement.
Refer to the Checklist for Feedback Sheets on ORE web site:
http://iris.uwaterloo.ca/ethics/human/application/samples/checklistfeedback.htm
See attached

D. POTENTIAL BENEFITS FROM THE STUDY

1. Identify and describe any known or anticipated direct benefits to the participants from their involvement in the project.
There are no particular benefits to participants in Stage 1. of this research

2.Identify and describe any known or anticipated benefits to the scientific community/society from the conduct of this study.
Methods, frameworks and metrics derived from this pilot study are novel and will inform the academic community's understanding of how data flow can be measured. The results of the pilot study, may be leveraged to inform the design of a larger, system-wide investigation to provide a system wide understanding of integration facilitated by electronic information exchange. There are preliminary discussions on use of the metrics and insight from this study to inform a more granular investigation of the impact of interoperability and information exchange on clinical workflows and patient outcomes. Data collected from the pilot study will contribute to a doctoral thesis investigating how particular antecedents can optimize interoperability and better enable a seamless flow of information between health providers.

Policy makers may benefit from our intent to use geospatial technology to map the results of the survey to examine how and where health information is being freely exchanged in the system. Depending on the design of Stage 2. we hope to be able to provide decision makers with valuable ex ante information to aid IT investment decision making related to interoperability.

E. POTENTIAL RISKS TO PARTICIPANTS FROM THE STUDY

1. For each procedure used in this study, describe any known or anticipated risks/stressors to the participants. Consider physiological, psychological, emotional, social, economic risks/stressors. A study–specific current health status form must be included when physiological assessments are used and the associated risk(s) to participants is minimal or greater.
No known or anticipated risks
The Stage 1.expert panel will be involve in a qualitative research project involving consensus

building discussion and ranking; this has no anticipated stress, risk or danger.

If the risk is greater than minimal and the study is industry sponsored, then Appendix B is to be completed.

2. Describe the procedures or safeguards in place to protect the physical and psychological health of the participants in light of the risks/stressors identified in E1.
N/a

F. INFORMED CONSENT PROCESS

Researchers are advised to review the Sample Materials section of the ORE website

Refer to sample information letters and consent forms:
http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

1. What process will be used to inform the potential participants about the study details and to obtain their consent for participation?
Information letter with written consent form

2. If written consent cannot be obtained from the potential participants, provide a justification for this.
N/a

3. Does this study involve persons who cannot give their own consent (e.g. minors)? No

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G. ANONYMITY OF PARTICIPANTS AND CONFIDENTIALITY OF DATA

1. Provide a detailed explanation of the procedures to be used to ensure anonymity of participants and confidentiality of data both during the research and in the release of the findings.
Stage 1. The Experts, in agreeing to participate, will consent to a process which involves face to face discussion. The nominal group process allows them to openly discuss their opinions, but to “rank” potential metrics for consideration, anonymously. Stage 2. While providers will not be referred to by name, they may be referred to by provider group and possibly geographic coordinates, therefore participation cannot be anonymous. Issues such as this will be addressed in the ORE 101 revision to be sent after October 26th when the Pilot Study location has been determined.

2. Describe the procedures for securing written records, video/audio tapes, questionnaires and recordings. Identify (i) whether the data collected will be linked with any other dataset and identify the linking dataset and (ii) whether the data will be sent outside of the institution where it is collected or if data will be received from other sites. For the latter, are the data de-identified, anonymized, or anonymous?
The researchers will keep a central record of Expert Identifiers, but these will be kept confidential. Data and discussion notes from Stage 1. will be stored on an encrypted flash drive and secured in a locked cupboard in the researcher’s office.

3. Indicate how long the data will be securely stored and the method to be used for final disposition of the

data.
Paper Records
Data will be retained indefinitely in a secure location.
Audio/Video Recordings
Data will be retained indefinitely in a secure location.
Electronic Data
Data will be retained indefinitely in a secure location.
Location: Encrypted electronic files and locked cabinet (paper files)

4. Are there conditions under which anonymity of participants or confidentiality of data cannot be guaranteed? No

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H. DECEPTION

1. Will this study involve the use of deception? No

Researchers must ensure that all supporting materials/documentation for their applications are submitted with the signed, hard copies of the ORE form 101/101A. Note, materials shown below in bold are normally required as part of the ORE application package. The inclusion of other materials depends on the specific type of projects.

Researchers are advised to review the Sample Materials section of the ORE web site:
http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

Protocol Involves a Drug, Medical Device, Biologic, or Natural Health Product

If the study procedures include administering or using a drug, medical device, biologic, or natural health product that has been or has not been approved for marketing in Canada then the researcher is to complete Appendix A, a Word document. Appendix A is to be attached to each of the two copies of the application that are submitted to the ORE. Information concerning studies involving a drug, biologic, natural health product, or medical devices can be found on the ORE website.

Drug , biologic or natural health product http://iris.uwaterloo.ca/ethics/human/researchTypes/clinical.htm

Medical devices: http://iris.uwaterloo.ca/ethics/human/researchTypes/devices.htm

Appendix A http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

Please **check** below all appendices that are attached as part of your application package:

- Recruitment Materials: A copy of any poster(s), flyer(s), advertisement(s), letter(s), telephone or other verbal script(s) used to recruit/gain access to participants.
- Information Letter and Consent Form(s)*. Used in studies involving interaction with

participants (e.g. interviews, testing, etc.)
- Feedback letter *

* Refer to sample letters:
http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

NOTE: The submission of incomplete application packages will increase the duration of the ethics review process.

To avoid common errors/omissions, and to minimize the potential for required revisions, applicants should ensure that their application and attachments are consistent with the *Checklist For Ethics Review of Human Research Application*

http://iris.uwaterloo.ca/ethics/form101/checklist.htm

Please note the submission of incomplete packages may result in delays in receiving full ethics clearance.
We suggest reviewing your application with the Checklist For Ethics Review of Human Research Applications
to minimize any required revisions and avoid common errors/omissions.
http://iris.uwaterloo.ca/ethics/form101/checklist.htm

INVESTIGATORS' AGREEMENT

I have read the Tri-Council Policy Statement (TCPS): Ethical Conduct for Research Involving Humans and agree to comply with the principles and articles outlined in the TCPS. In the case of student research, as Faculty Supervisor, my signature indicates that I have read and approved this application and the thesis proposal, deem the project to be valid and worthwhile, and agree to provide the necessary supervision of the student.

______________________________	______________________
Signature of Principal Investigator/Supervisor	**Date**
______________________________	______________________
Signature of Student Investigator	**Date**
	______________________
FOR OFFICE OF RESEARCH ETHICS USE ONLY:	**Date**

____
Susan E. Sykes, Ph.D., C. Psych.
Director, Office of Research Ethics
OR
Susanne Santi, M.Math
Senior Manager, Research Ethics
OR

Julie Joza, B.Sc.
Manager, Research Ethics

ORE 101
Revised August 2003

Appendix E. Application for Ethics Review for Regional Survey

ORE OFFICE USE ONLY

ORE #_______________

APPLICATION FOR ETHICS REVIEW OF RESEARCH INVOLVING HUMAN PARTICIPANTS

Please remember to PRINT AND SIGN the form, and forward TWO copies to the Office of Research Ethics, Needles Hall, Room 1024, with all attachments.

A. GENERAL INFORMATION

1. Title of Project: Measuring health system integration through electronic information exchange - Making the invisible visible

2. a) Principal and Co-Investigator(s)

Name	Department	Ext:	e-mail:
Dr. Ian McKillop (faculty)	Health Studies & Gerontology37127	37127	ian@uwaterloo.ca
Dr. Ross Baker (faculty)	University of Toronto	416 978 7804	ross.baker@utoronto.ca

2. b) Collaborator(s)

Name	Department	Ext:	e-mail:

3. Faculty Supervisor(s)

Name	Department	Ext:	e-mail:
Dr. Ian McKillop	Health Studies & Gerontology	37127	ian @uwaterloo.ca

4. Student Investigator(s)

Name	Department	Ext:	e-mail:	Local Phone #:
Josephine McMurray	Health Studies & Gerontology	37053	djbmcmur@uwaterloo.ca	519 242 7477

5. Level of Project: PhD **Specify Course:**

Research Project/Course Status: Pilot Research

6. Funding Status (if there is an industry sponsor and procedures pose greater than minimal risk, then Appendix B is to be completed):

Is this project currently funded? Yes

- If Yes, provide Name of Sponsor and include the title of the grant/contract: Other : Health System Performance Research Network

- If No, is funding being sought OR if Yes, is additional funding being sought? Yes
    - o Funding Name of Sponsor and title of grant/contract:
- Period of Funding: July 1, 2009 - March 31, 2009

7. Does this research involve another institution or site? Yes
If Yes, what other institutions or sites are involved:
University of Toronto

8. Has this proposal been, or will it be, submitted to any other Research Ethics Board/Institutional Review Board? No

9. For Undergraduate and Graduate Research:

Has this proposal received approval of a Department Committee? Not Dept. Req.

10. a) Indicate the anticipated commencement date for this project: 3/1/2010

b) Indicate the anticipated completion date for this project: 9/30/2010

B. SUMMARY OF PROPOSED RESEARCH

1. Purpose and Rationale for Proposed Research

a. Describe the purpose (objectives) and rationale of the proposed project and include any hypothesis(es)/research questions to be investigated. For a clinical trial/medical device testing summarize the research proposal using the following headings: Purpose, Hypothesis, Justification, and Objectives. Where available, provide a copy of a research proposal. For a clinical trial/medical device testing a research proposal is required:
Rationale
A 2008 report by the Commonwealth Fund identified six attributes of what experts described as an “ideal healthcare system” based on their demonstrated ability to drive high performance (Shih et al., 2008).The first driver explicitly calls for the electronic exchange of “relevant clinical information” to appropriate providers and the patient. Efficient exchanges of information across the system are implied in all five of the other attributes.
Improving inter-organizational information exchange, making it faster, more accurate, more secure, and allowing users to capture information from different sources, facilitates integration and care coordination (Pink et al., 2000) with consequent improvement in quality and reduced duration of care (Stiell, et al., 2003; van Walraven et al., 2008), increased accessibility (Durbin et al., 2001),cost reduction from fewer redundant medical procedures(Smith et al., 2008), reduced patient transfers (Hodge, 2008), and improvements to medical error rates (Schabetsberger et al., 2006).
Integrated care has been presented as a solution for the long term sustainability of health systems; information systems which facilitate the flow of information across the continuum of

care are considered pivotal to that integration agenda {{2671 Suter, E. 2009{{2077 Conrad,Douglas A. 1996}}}}. The key role of IT-enabled inter-organizational communication and system integration has been documented in other sectors (Oh et al., 2007).

To date, over $2 billion has been invested by Canada’s federal government, and considerably more by provinces and individual healthcare organizations [such as hospitals, physicians, labs, long term care facilities and public health agencies], to enable the electronic capture and exchange of health information. While each organization may be accountable to stakeholders for the impact of these investments, the only meaningful indicator of success measured by inter-provider electronic information exchange, is the impact they have had on system-level integration. There is currently no such metric; therefore no systematic way to assess 1.our progress towards developing an integrated system of shared patient information, and 2. the value of our investment to date. This research study will address those gaps.

Purpose

To develop a reliable, valid and sensitive metric which captures the intensity of electronic information exchange between healthcare organizations in Ontario’s health system. From these organizational-level measures, a system-level measure of health services integration will be derived. Gaps in electronic information exchange will be analysed . The results from this research may be used to make more informed decisions about strategic priorities and resource allocation in support of improved health system integration.

Assertions

1. There are currently few reliable measures of system-level integration between healthcare providers.
2. Electronic information exchange is a key enabler of health system integration. Electronic information exchange between provider information systems occurs along a continuum: from an isolated system with no electronic flows of data to one which is fully integrated with data flows completely electronically transportable, organisable and interpretable.
3. A framework, to comprehensively describe the components of electronic information exchange between healthcare providers in a system, and thus its integration, has the following dimensions which can be measured:

a. The Technical Architecture;
b. The Message;
c. The Information Flow; and
d. The Outcome (Level of Integration)

4. Electronic information exchange is a key enabler of the flow of clinical in a health system. It is the sum of electronic information flows between healthcare providers in the system; an aggregate measure of those information flows provides a lead indicator of the level of integration within a health system. This information may facilitate cross-system analysis of the impact of IT investments and integration outcomes.

b. In lay language, provide a one paragraph (approximately 100 words) summary of the project including purpose, the anticipated potential benefits, and basic procedures used.

Integration of the Ontario health system is seen as an essential component of its future sustainability, and to improvements in both safety and quality. Electronic transfer of information is considered a key component of integration, yet there are gaps in our understanding of where, how, why and to what extent information flows. This project’s unique contribution will be to develop a reliable, valid, and sensitive system-level metric for inter-organizational electronic information exchange in healthcare. Using a variety of quantitative and qualitative methods, data will be collected, collated, analyzed, a metric developed to improve our understanding of information flowing between health system participants. This will be positioned as a lead indicator of system integration. Analysis of collected data has the potential to assist in making more informed decisions about strategic priorities and resource allocation in support of improved system integration.

C. DETAILS OF STUDY

1. Methodology/Procedures

a. Indicate all of the procedures that will be used. Append to form 101 a copy of all materials to be used in this study.

Survey(s) or questionnaire(s) (in person) All are standardized.
Computer-administered task(s) or survey(s) All are standardized.
Interview(s) (in person)
Interview(s) (by telephone)
Audio-recording
Analysis of secondary data set

b. Provide a detailed, sequential description of the procedures to be used in this study. For studies involving multiple procedures or sessions, provide a flow chart. Where applicable, this section also should give the research design (e.g., cross-over design, repeated measures design).
See attached Research Methods Flow Chart

c. Will this study involve the administration/use of any drug, medical device, biologic, or natural health product? No

2. Participants Involved in the Study

a. Indicate who will be recruited as potential participants in this study.
Non-UW Participants:
Adults

b. Describe the potential participants in this study including group affiliation, gender, age range and any other special characteristics. Describe distinct or common characteristics of the potential participants or a group (e.g., a group with a particular health condition) that are relevant to recruitment and/or procedures (e.g., A group with asbestosis is included. People with this condition tend to be male, 50+ years, worked with asbestos.). If only one gender is to be selected for recruitment, provide a justification for this.

Healthcare providers in the region of [name withheld]. The research is being conducted at the organizational level. One representative who is identified by the organization as capable of making decisions about the organization's information technology will complete the survey. There are no other limitations.

c. How many participants are expected to be involved in this study? For a clinical trial, medical device testing, or study with procedures that pose greater than minimal risk, sample size determination information is to be provided, as outlined in Guidance Note C2c.

Sample population is approximately 660 entities and includes public health units, physician offices, hospitals, pharmacies, community care access centres, long term care homes, diagnostic imaging and laboratory facilities. Approximately 350 participants are required for

95% confidence level and 5% margin of error.

3. Recruitment Process and Study Location

a. From what source(s) will the potential participants be recruited?
Agencies
Healthcare settings, nursing homes etc.

b. Describe how and by whom the potential participants will be recruited. Provide a copy of any materials to be used for recruitment (e.g. posters(s), flyers, cards, advertisement(s), letter(s), telephone, email, and other verbal scripts).
The Doctoral Student will coordinate the recruitment process. A yellow pages database and other publicly available information online ([name withheld] LHIN, College of Physicians and Surgeons etc.)will be used to create a database of potential respondents. Please see attached verbal script, email and fax templates which will be used. Students will be used to try to identify the person with whom we should communicate in the organization. If required, participants may visit our website to get more information on the project, otherwise an email will be sent to them with the information on the project and link to the survey at which time they will make the decision as to whether they would like to participate. See attached documents: Phone recruitment script/guidelines Fax response to request for more information Email response to request for more information Fax survey introduction Email survey introduction

c. Where will the study take place? On campus: Online Off campus: Some site visits will occur to pilot the survey questionnaire and to triangulate the results once collected.

4. Remuneration for Participants

Will participants receive remuneration (financial, in-kind, or otherwise) for participation? No

5. Feedback to Participants

Describe the plans for provision of study feedback and attach a copy of the feedback letter to be used. Wherever possible, written feedback should be provided to study participants including a statement of appreciation, details about the purpose and predictions of the study, restatement of the provisions for confidentiality and security of data, an indication of when a study report will be available and how to obtain a copy, contact information for the researchers, and the ethics review and clearance statement.
Refer to the Checklist for Feedback Sheets on ORE web site:
http://iris.uwaterloo.ca/ethics/human/application/samples/checklistfeedback.htm
The following text is included in the faxed surveys and will be included in the online version. The content of the final report will be determined as the research results are gathered:

Thank you for taking the time to complete this questionnaire.

A summary of the results from this research will be available to participants in early Fall, 2010.

Please indicate here if you would like a summary sent via email when it is complete. ƒ¥
Alternately, you may visit www.meie.uwaterloo.ca to review the report or download a copy. We would be delighted to speak to groups or organizations about the results when they are available.

D. POTENTIAL BENEFITS FROM THE STUDY

1. Identify and describe any known or anticipated direct benefits to the participants from their involvement in the project.

Benefits will accrue to policy makers and the academic community rather than to providers directly. Some data on technology infrastructure which supports information exchange might be shared with participants; articles and presentations relating the projects results will be available to interested participants.

2.Identify and describe any known or anticipated benefits to the scientific community/society from the conduct of this study.

There are currently no leading indicators of health system integration related to information exchange, considered a necessary construct for integration. A reliable, valid and sensitive metric which captures the intensity of electronic information exchange between healthcare organizations in Ontario's health system will be developed. From these organizational-level measures, a system-level measure of health services integration will be derived. Gaps in electronic information exchange will be analysed. The results from this research may be used to make more informed decisions about strategic priorities and resource allocation in support of improved health system integration.

E. POTENTIAL RISKS TO PARTICIPANTS FROM THE STUDY

1. For each procedure used in this study, describe any known or anticipated risks/stressors to the participants. Consider physiological, psychological, emotional, social, economic risks/stressors. A study–specific current health status form must be included when physiological assessments are used and the associated risk(s) to participants is minimal or greater.

No known or anticipated risks

Interviews for the pilot study are with health professionals regarding non-personal information sharing. No information about patients or their care is being requested or used. Any data collected will remain confidential.

If the risk is greater than minimal and the study is industry sponsored, then Appendix B is to be completed.

2. Describe the procedures or safeguards in place to protect the physical and psychological health of the participants in light of the risks/stressors identified in E1.

The risk of psychological or physical risk to participants is negligible.

F. INFORMED CONSENT PROCESS

Researchers are advised to review the Sample Materials section of the ORE website

Refer to sample information letters and consent forms:
http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

1. What process will be used to inform the potential participants about the study details and to obtain their consent for participation?

Information/cover letter

Survey participants will view consent information online.

2. If written consent cannot be obtained from the potential participants, provide a justification for this.

3. Does this study involve persons who cannot give their own consent (e.g. minors)? No

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G. ANONYMITY OF PARTICIPANTS AND CONFIDENTIALITY OF DATA

1. Provide a detailed explanation of the procedures to be used to ensure anonymity of participants and confidentiality of data both during the research and in the release of the findings.
Providers will be described but not identified; a numeric code will be used to link data.

2. Describe the procedures for securing written records, video/audio tapes, questionnaires and recordings. Identify (i) whether the data collected will be linked with any other dataset and identify the linking dataset and (ii) whether the data will be sent outside of the institution where it is collected or if data will be received from other sites. For the latter, are the data de-identified, anonymized, or anonymous?
The data from this study will be retained on a password protected server for 6 months after which all but the summaries will be erased. Only the researchers listed will have access to the data.

3. Indicate how long the data will be securely stored and the method to be used for final disposition of the data.
Paper Records
Data will be retained indefinitely in a secure location.
Audio/Video Recordings
Data will be retained indefinitely in a secure location.
Electronic Data
Data will be retained indefinitely in a secure location.
Location: Ideas for Health Research Laboratory

4. Are there conditions under which anonymity of participants or confidentiality of data cannot be guaranteed? Yes

If Yes, please provide details:
Where participant organizations are one of less than five in a sector i.e. public health, CCAC, their responses may be identifiable. Should these data be critical to the study results, the individual organizations will be contacted for their express consent to allow the publication of the data. Given the nature of the information being collected i.e. it is in the public domain, we do not anticipate concerns.

H. DECEPTION

1. Will this study involve the use of deception? No

Researchers must ensure that all supporting materials/documentation for their applications are submitted with the signed, hard copies of the ORE form 101/101A. Note, materials shown below in bold are normally required as part of the ORE application package. The inclusion of other materials depends on the specific type of projects.

Researchers are advised to review the Sample Materials section of the ORE web site:
http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

Protocol Involves a Drug, Medical Device, Biologic, or Natural Health Product

If the study procedures include administering or using a drug, medical device, biologic, or natural health product that has been or has not been approved for marketing in Canada then the researcher is to complete Appendix A, a Word document. Appendix A is to be attached to each of the two copies of the application that are submitted to the ORE. Information concerning studies involving a drug, biologic, natural health product, or medical devices can be found on the ORE website.

Drug , biologic or natural health product http://iris.uwaterloo.ca/ethics/human/researchTypes/clinical.htm

Medical devices: http://iris.uwaterloo.ca/ethics/human/researchTypes/devices.htm

Appendix A http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

Please **check** below all appendices that are attached as part of your application package:

- Recruitment Materials: A copy of any poster(s), flyer(s), advertisement(s), letter(s), telephone or other verbal script(s) used to recruit/gain access to participants.
- Information Letter and Consent Form(s)*. Used in studies involving interaction with participants (e.g. interviews, testing, etc.)
- Data Collection Materials: A copy of all survey(s), questionnaire(s), interview questions, interview themes/sample questions for open-ended interviews, focus group questions, or any standardized tests.

* Refer to sample letters:
http://iris.uwaterloo.ca/ethics/human/application/101samples.htm

NOTE: The submission of incomplete application packages will increase the duration of the ethics review process.

To avoid common errors/omissions, and to minimize the potential for required revisions, applicants should ensure that their application and attachments are consistent with the *Checklist For Ethics Review of Human Research Application*

http://iris.uwaterloo.ca/ethics/form101/checklist.htm

Please note the submission of incomplete packages may result in delays in receiving full ethics clearance.
We suggest reviewing your application with the Checklist For Ethics Review of Human Research Applications
to minimize any required revisions and avoid common errors/omissions.
http://iris.uwaterloo.ca/ethics/form101/checklist.htm

INVESTIGATORS' AGREEMENT

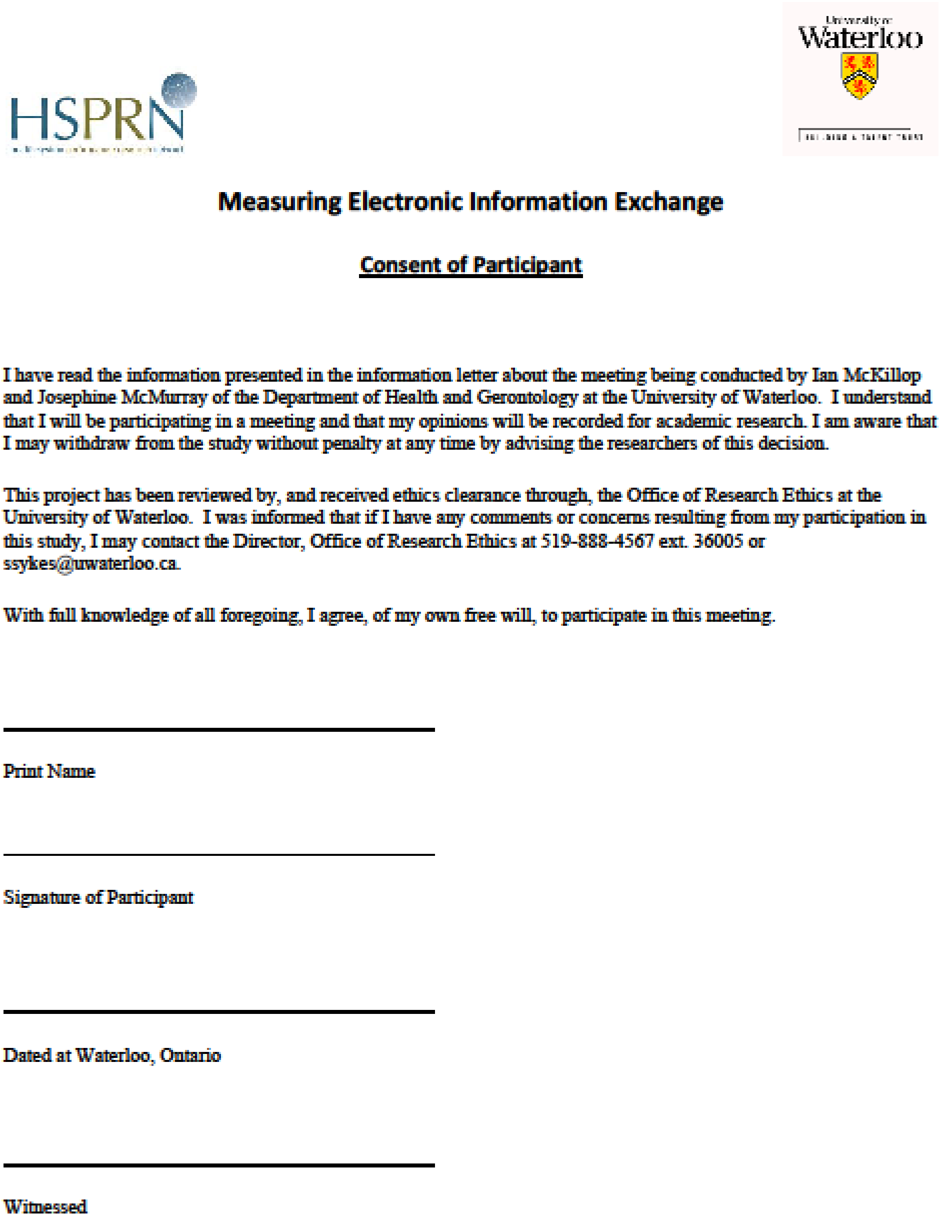
I have read the Tri-Council Policy Statement (TCPS): Ethical Conduct for Research Involving Humans and agree to comply with the principles and articles outlined in the TCPS. In the case of student research, as Faculty Supervisor, my signature indicates that I have read and approved this application and the thesis proposal, deem the project to be valid and worthwhile, and agree to provide the necessary supervision of the student.

____	___________________________
Signature of Principal Investigator/Supervisor	**Date**
_______________________________________	___________________________
Signature of Student Investigator	**Date**
	___________________________
FOR OFFICE OF RESEARCH ETHICS USE ONLY:	**Date**

____
Susan E. Sykes, Ph.D., C. Psych.
Director, Office of Research Ethics
OR
Susanne Santi, M.Math
Senior Manager, Research Ethics
OR
Julie Joza, B.Sc.
Manager, Research Ethics

ORE 101
Revised August 2003

Appendix F. Nominal Group Process - Consent



Measuring Electronic Information Exchange

Consent of Participant

I have read the information presented in the information letter about the meeting being conducted by Ian McKillop and Josephine McMurray of the Department of Health and Gerontology at the University of Waterloo. I understand that I will be participating in a meeting and that my opinions will be recorded for academic research. I am aware that I may withdraw from the study without penalty at any time by advising the researchers of this decision.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 519-888-4567 ext. 36005 or ssykes@uwaterloo.ca.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this meeting.

____

Print Name

____

Signature of Participant

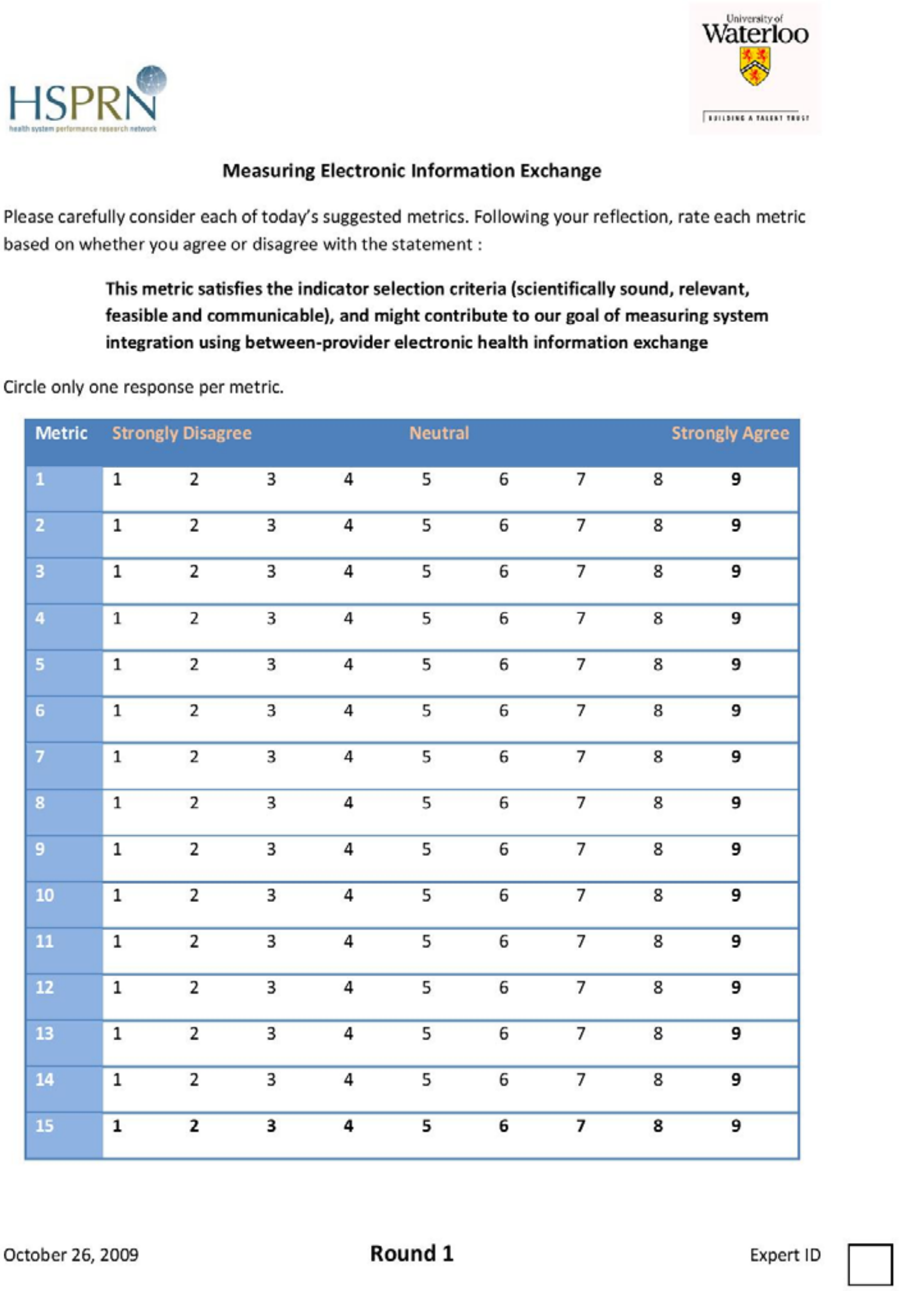
____

Dated at Waterloo, Ontario

____

Witnessed

Appendix G. Nominal Group Technique Ranking Sheet



HSPRN
health system performance research network

University of
Waterloo
BUILDING A TALENT TRUST

Measuring Electronic Information Exchange

Please carefully consider each of today's suggested metrics. Following your reflection, rate each metric based on whether you agree or disagree with the statement :

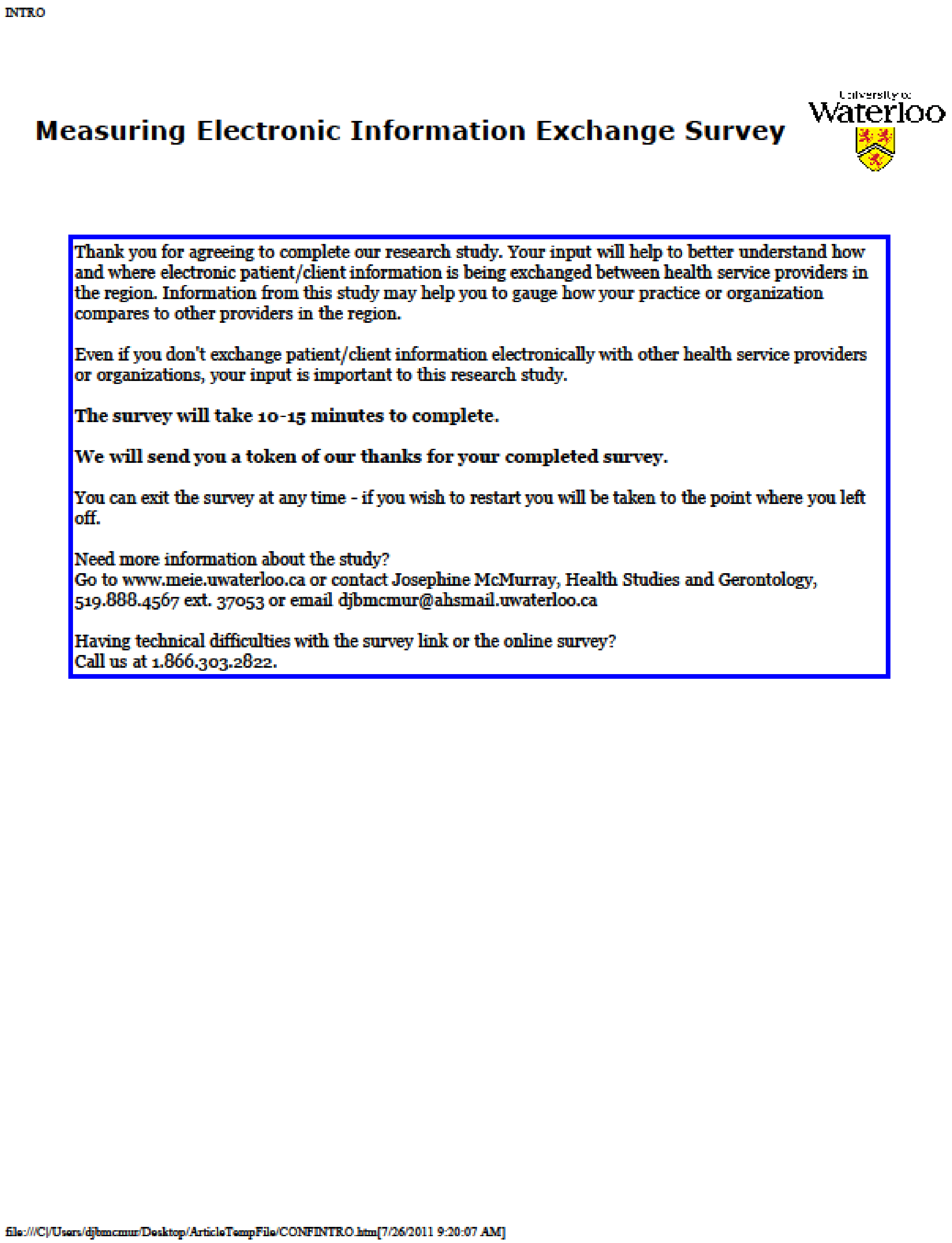
> **This metric satisfies the indicator selection criteria (scientifically sound, relevant, feasible and communicable), and might contribute to our goal of measuring system integration using between-provider electronic health information exchange**

Circle only one response per metric.

Metric	Strongly Disagree				Neutral				Strongly Agree
1	1	2	3	4	5	6	7	8	**9**
2	1	2	3	4	5	6	7	8	**9**
3	1	2	3	4	5	6	7	8	**9**
4	1	2	3	4	5	6	7	8	**9**
5	1	2	3	4	5	6	7	8	**9**
6	1	2	3	4	5	6	7	8	**9**
7	1	2	3	4	5	6	7	8	**9**
8	1	2	3	4	5	6	7	8	**9**
9	1	2	3	4	5	6	7	8	**9**
10	1	2	3	4	5	6	7	8	**9**
11	1	2	3	4	5	6	7	8	**9**
12	1	2	3	4	5	6	7	8	**9**
13	1	2	3	4	5	6	7	8	**9**
14	1	2	3	4	5	6	7	8	**9**
15	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

October 26, 2009 **Round 1** Expert ID ☐

Appendix H. Questionnaire (Web Version)



INTRO

Measuring Electronic Information Exchange Survey

University of Waterloo

Thank you for agreeing to complete our research study. Your input will help to better understand how and where electronic patient/client information is being exchanged between health service providers in the region. Information from this study may help you to gauge how your practice or organization compares to other providers in the region.

Even if you don't exchange patient/client information electronically with other health service providers or organizations, your input is important to this research study.

The survey will take 10-15 minutes to complete.

We will send you a token of our thanks for your completed survey.

You can exit the survey at any time - if you wish to restart you will be taken to the point where you left off.

Need more information about the study?
Go to www.meie.uwaterloo.ca or contact Josephine McMurray, Health Studies and Gerontology, 519.888.4567 ext. 37053 or email djbmcmur@ahsmail.uwaterloo.ca

Having technical difficulties with the survey link or the online survey?
Call us at 1.866.303.2822.

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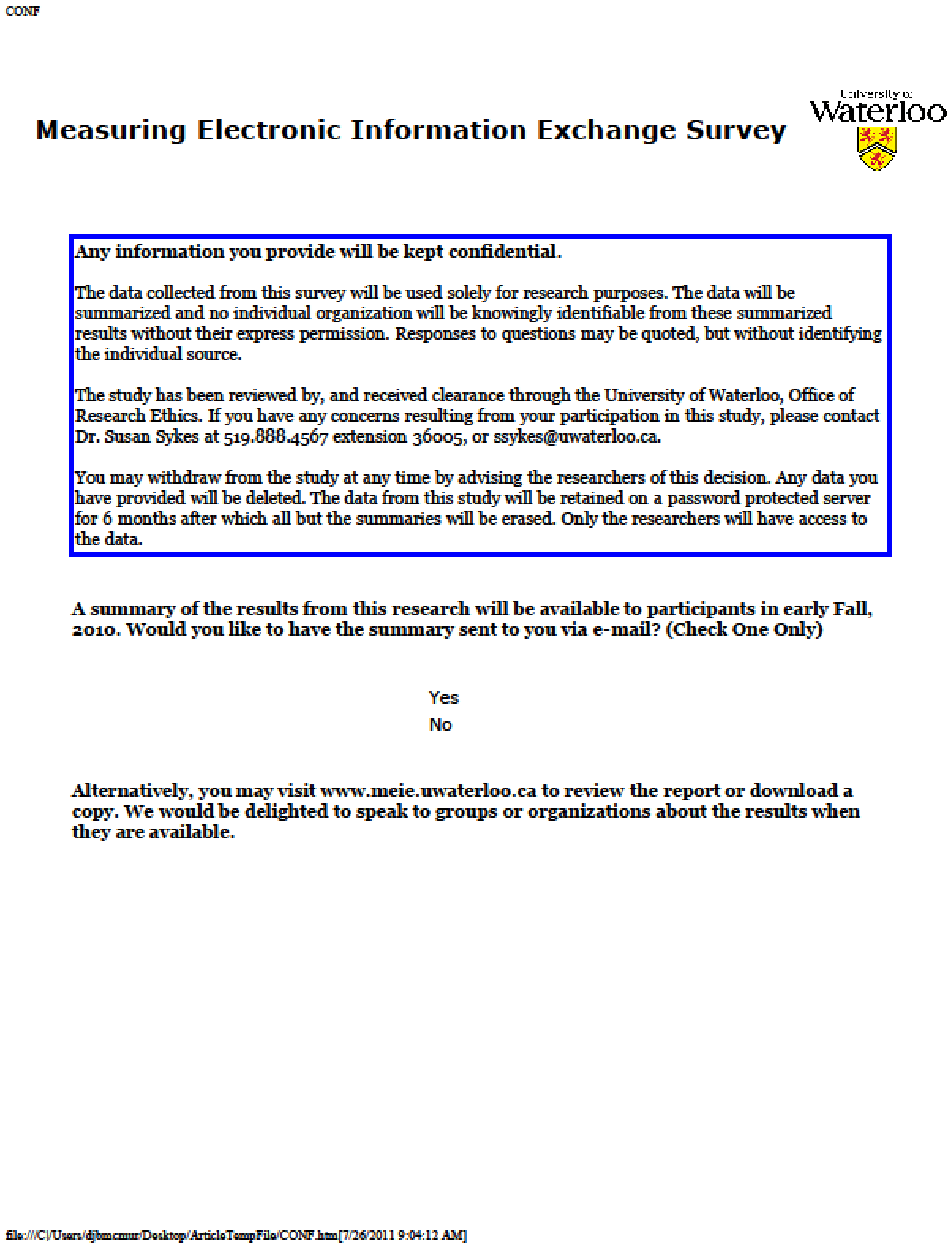

CONF

Measuring Electronic Information Exchange Survey

Any information you provide will be kept confidential.

The data collected from this survey will be used solely for research purposes. The data will be summarized and no individual organization will be knowingly identifiable from these summarized results without their express permission. Responses to questions may be quoted, but without identifying the individual source.

The study has been reviewed by, and received clearance through the University of Waterloo, Office of Research Ethics. If you have any concerns resulting from your participation in this study, please contact Dr. Susan Sykes at 519.888.4567 extension 36005, or ssykes@uwaterloo.ca.

You may withdraw from the study at any time by advising the researchers of this decision. Any data you have provided will be deleted. The data from this study will be retained on a password protected server for 6 months after which all but the summaries will be erased. Only the researchers will have access to the data.

A summary of the results from this research will be available to participants in early Fall, 2010. Would you like to have the summary sent to you via e-mail? (Check One Only)

Yes
No

Alternatively, you may visit www.meie.uwaterloo.ca to review the report or download a copy. We would be delighted to speak to groups or organizations about the results when they are available.

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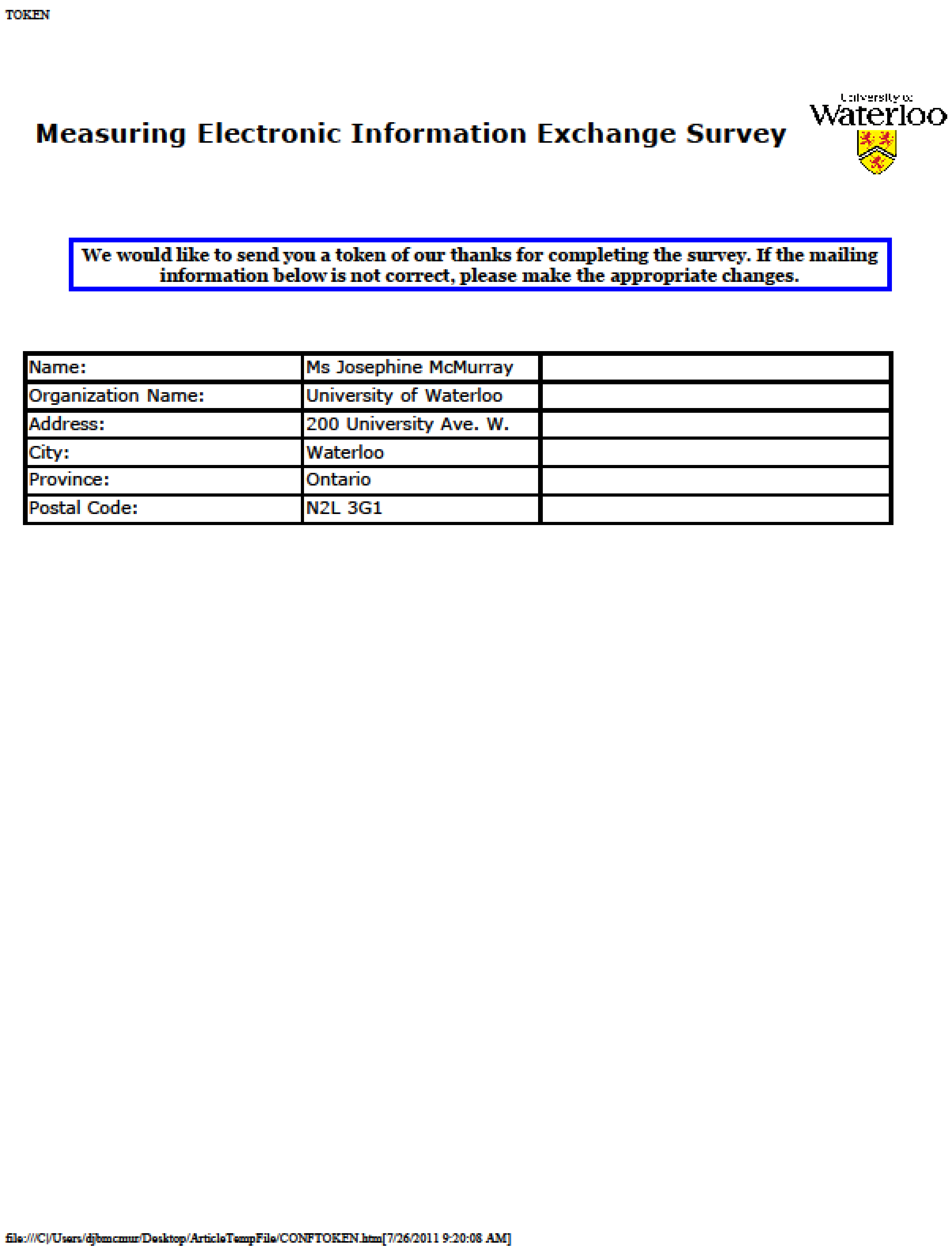

TOKEN

Measuring Electronic Information Exchange Survey

University of Waterloo

We would like to send you a token of our thanks for completing the survey. If the mailing information below is not correct, please make the appropriate changes.

Name:	Ms Josephine McMurray	
Organization Name:	University of Waterloo	
Address:	200 University Ave. W.	
City:	Waterloo	
Province:	Ontario	
Postal Code:	N2L 3G1	

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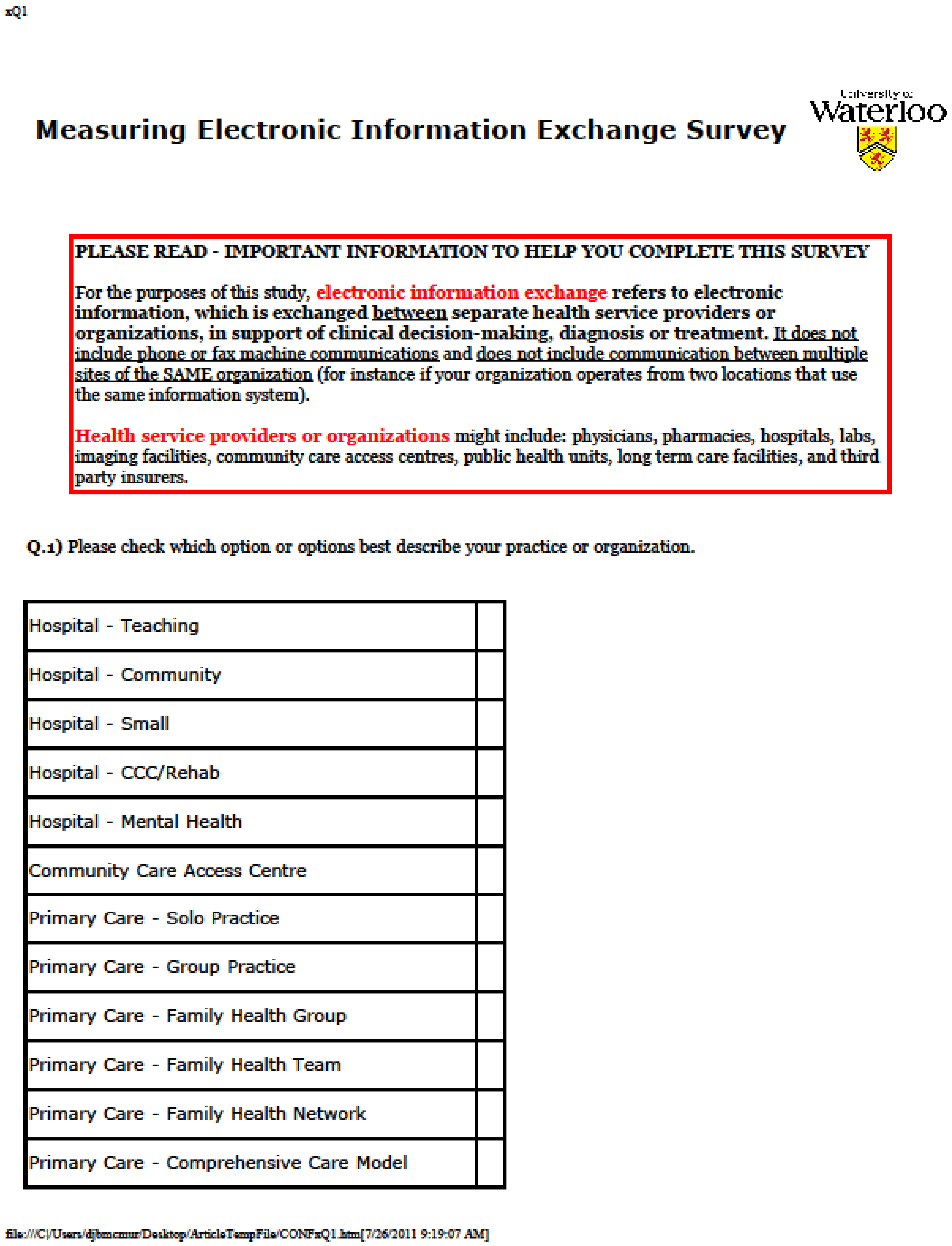


Measuring Electronic Information Exchange Survey

University of Waterloo

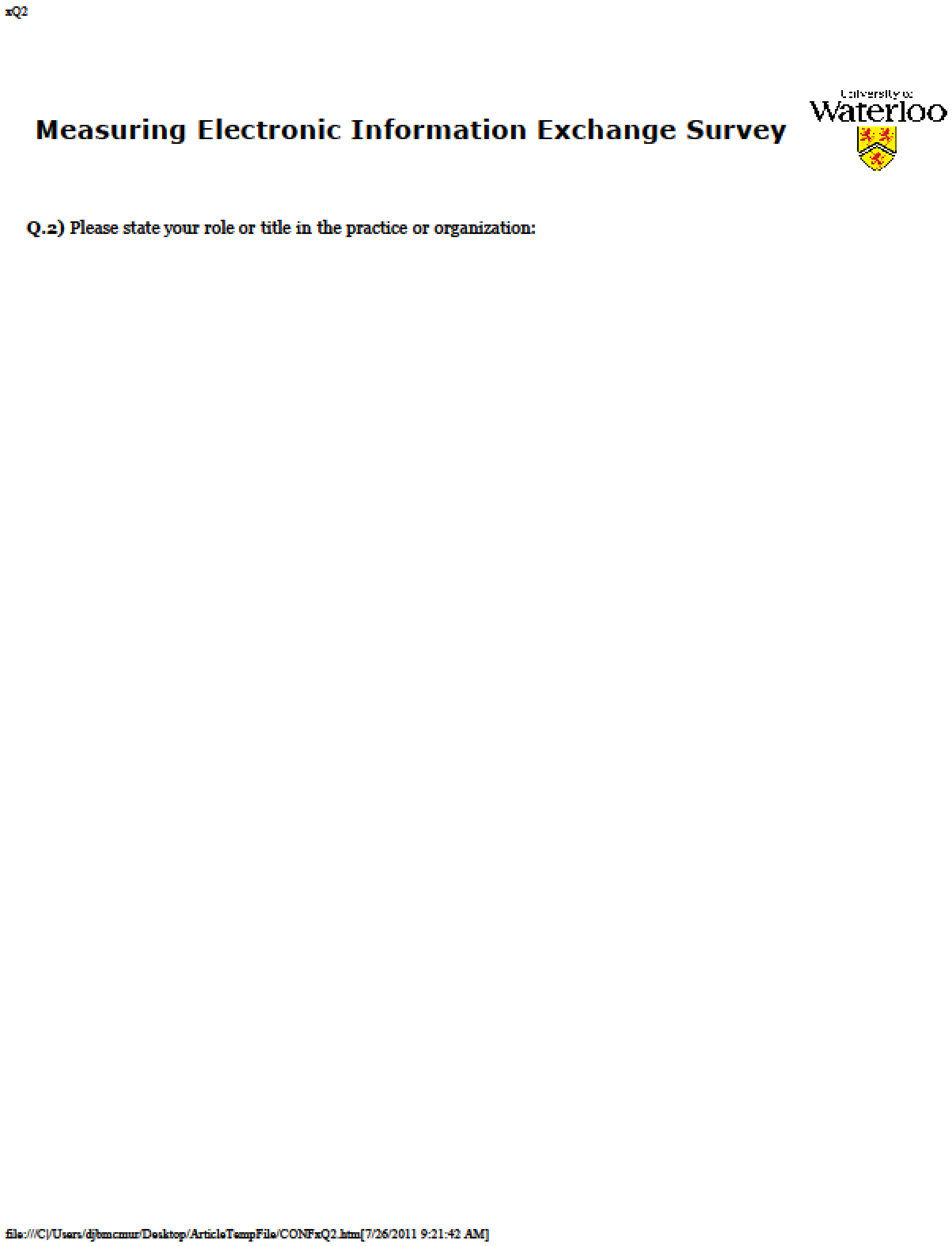
PLEASE READ - IMPORTANT INFORMATION TO HELP YOU COMPLETE THIS SURVEY

For the purposes of this study, **electronic information exchange refers to electronic information, which is exchanged __between__ separate health service providers or organizations, in support of clinical decision-making, diagnosis or treatment.** __It does not include phone or fax machine communications__ and __does not include communication between multiple sites of the SAME organization__ (for instance if your organization operates from two locations that use the same information system).

Health service providers or organizations might include: physicians, pharmacies, hospitals, labs, imaging facilities, community care access centres, public health units, long term care facilities, and third party insurers.

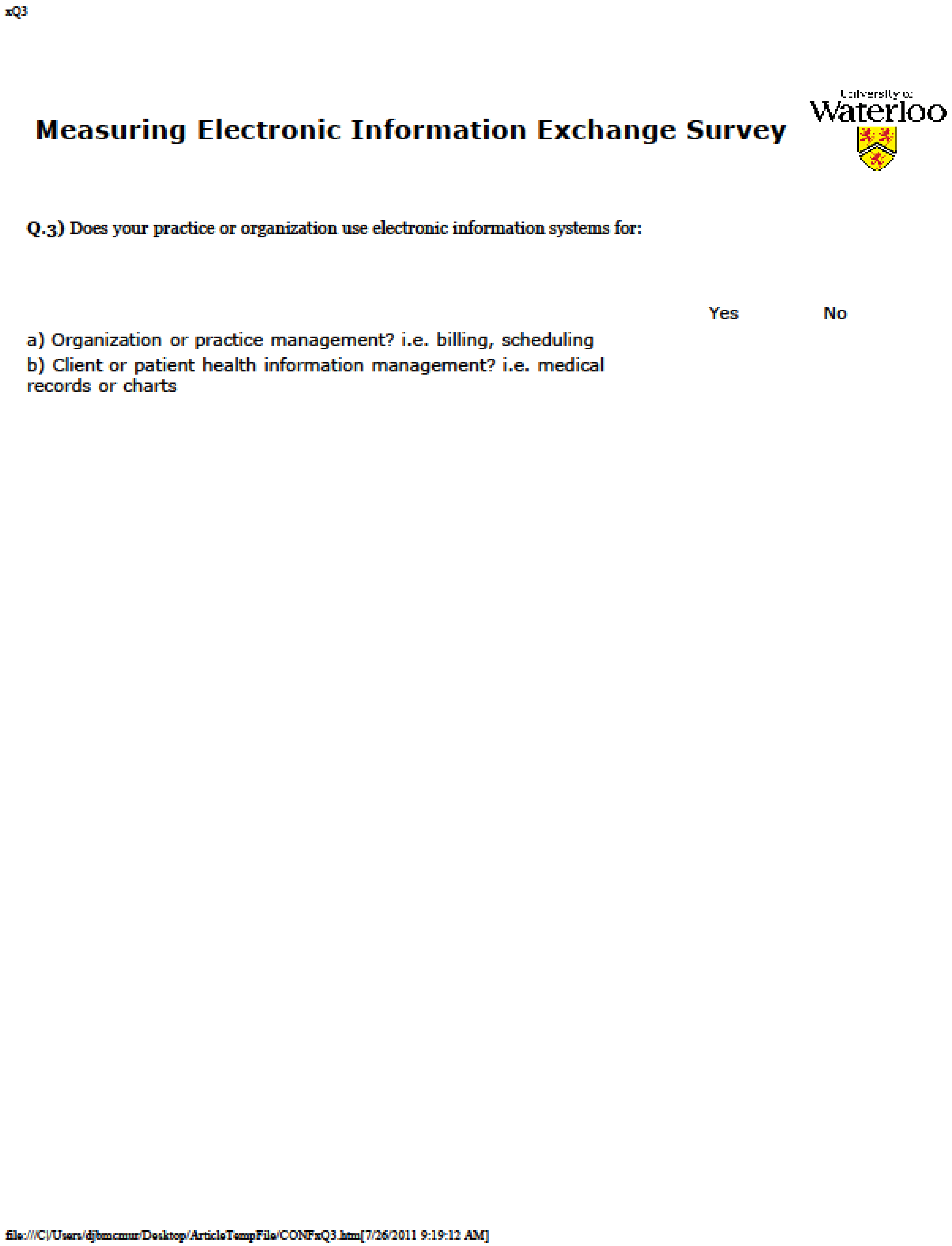
Q.1) Please check which option or options best describe your practice or organization.

Hospital - Teaching	
Hospital - Community	
Hospital - Small	
Hospital - CCC/Rehab	
Hospital - Mental Health	
Community Care Access Centre	
Primary Care - Solo Practice	
Primary Care - Group Practice	
Primary Care - Family Health Group	
Primary Care - Family Health Team	
Primary Care - Family Health Network	
Primary Care - Comprehensive Care Model	



Measuring Electronic Information Exchange Survey

Q.2) Please state your role or title in the practice or organization:



xQ3

Measuring Electronic Information Exchange Survey

Q.3) Does your practice or organization use electronic information systems for:

	Yes	No
a) Organization or practice management? i.e. billing, scheduling		
b) Client or patient health information management? i.e. medical records or charts		

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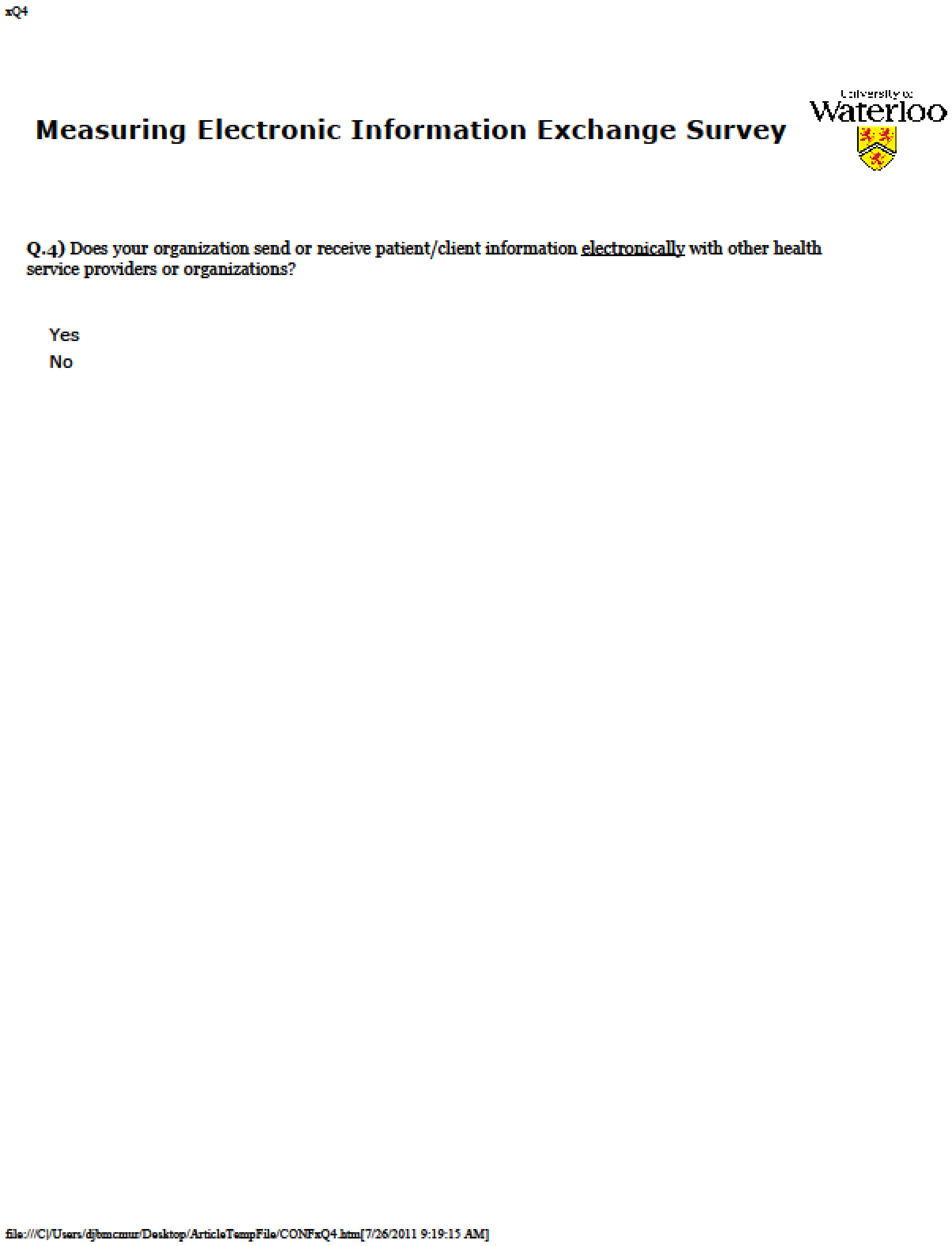

xQ4

Measuring Electronic Information Exchange Survey

Q.4) Does your organization send or receive patient/client information electronically with other health service providers or organizations?

Yes
No

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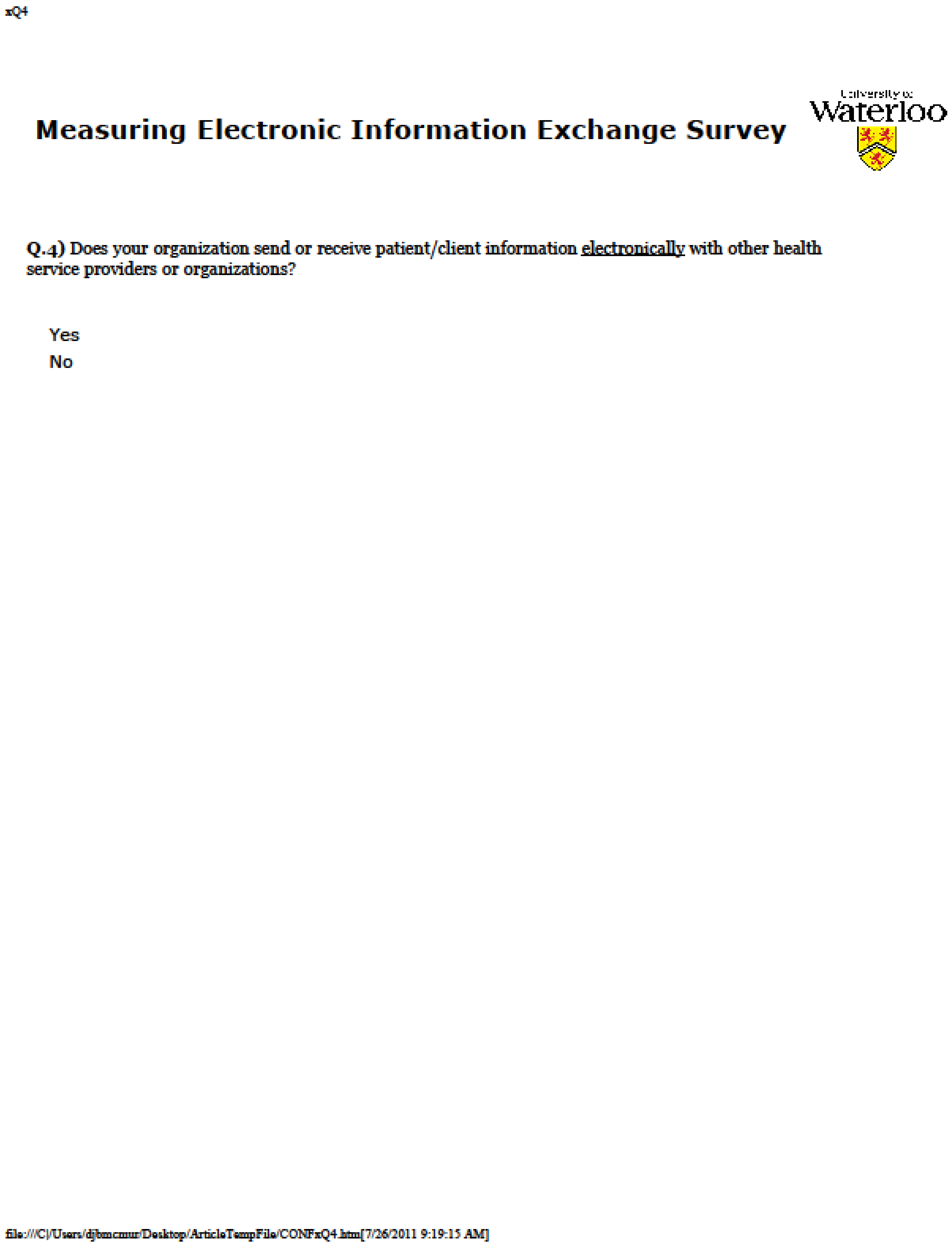

xQ4

Measuring Electronic Information Exchange Survey

University of Waterloo

Q.4) Does your organization send or receive patient/client information electronically with other health service providers or organizations?

Yes

No

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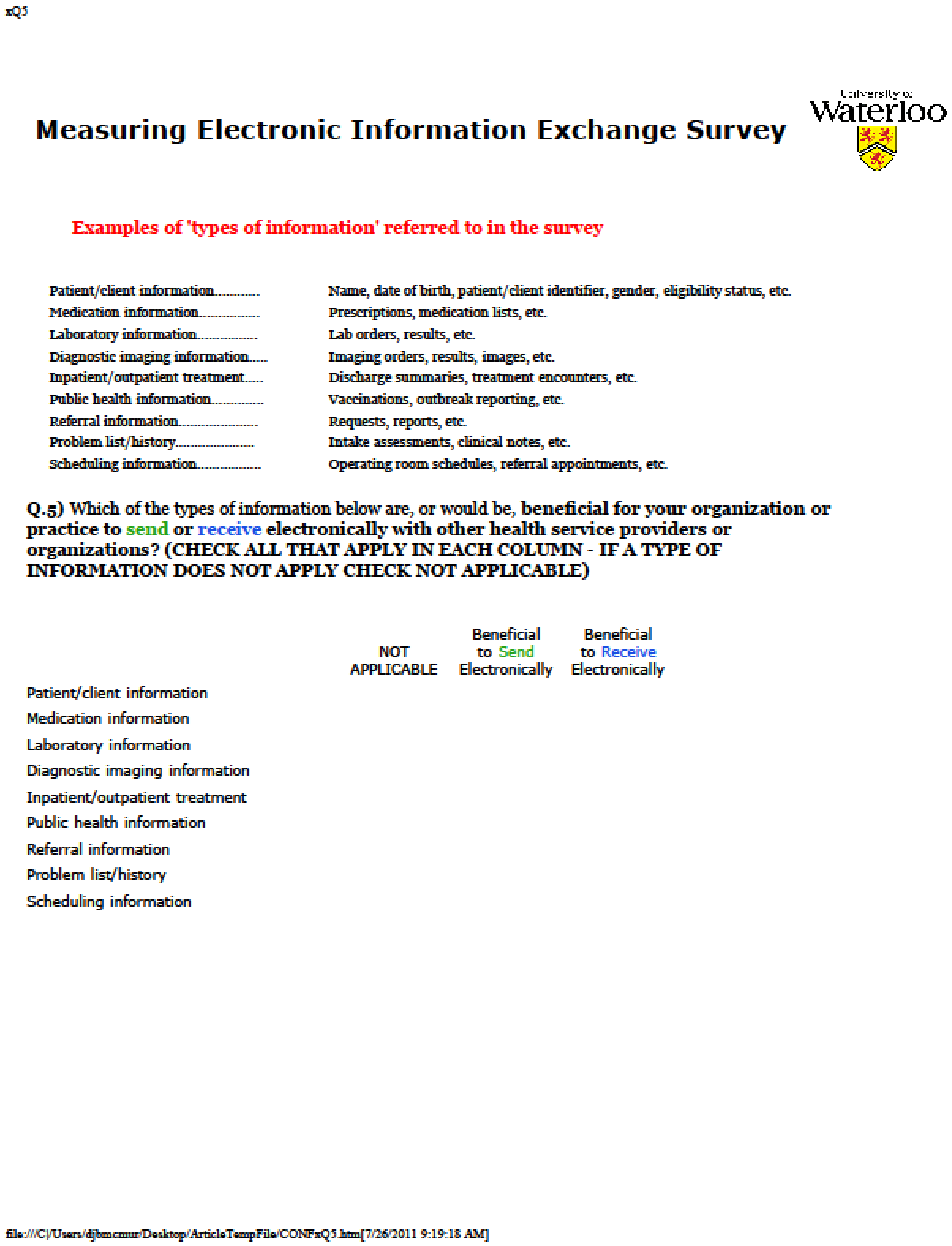

xQ5

Measuring Electronic Information Exchange Survey

Examples of 'types of information' referred to in the survey

Patient/client information...........	Name, date of birth, patient/client identifier, gender, eligibility status, etc.
Medication information................	Prescriptions, medication lists, etc.
Laboratory information................	Lab orders, results, etc.
Diagnostic imaging information.....	Imaging orders, results, images, etc.
Inpatient/outpatient treatment.....	Discharge summaries, treatment encounters, etc.
Public health information.............	Vaccinations, outbreak reporting, etc.
Referral information.....................	Requests, reports, etc.
Problem list/history.....................	Intake assessments, clinical notes, etc.
Scheduling information.................	Operating room schedules, referral appointments, etc.

Q.5) Which of the types of information below are, or would be, **beneficial for your organization or practice to send or receive electronically with other health service providers or organizations? (CHECK ALL THAT APPLY IN EACH COLUMN - IF A TYPE OF INFORMATION DOES NOT APPLY CHECK NOT APPLICABLE)**

	NOT APPLICABLE	Beneficial to Send Electronically	Beneficial to Receive Electronically
Patient/client information			
Medication information			
Laboratory information			
Diagnostic imaging information			
Inpatient/outpatient treatment			
Public health information			
Referral information			
Problem list/history			
Scheduling information			

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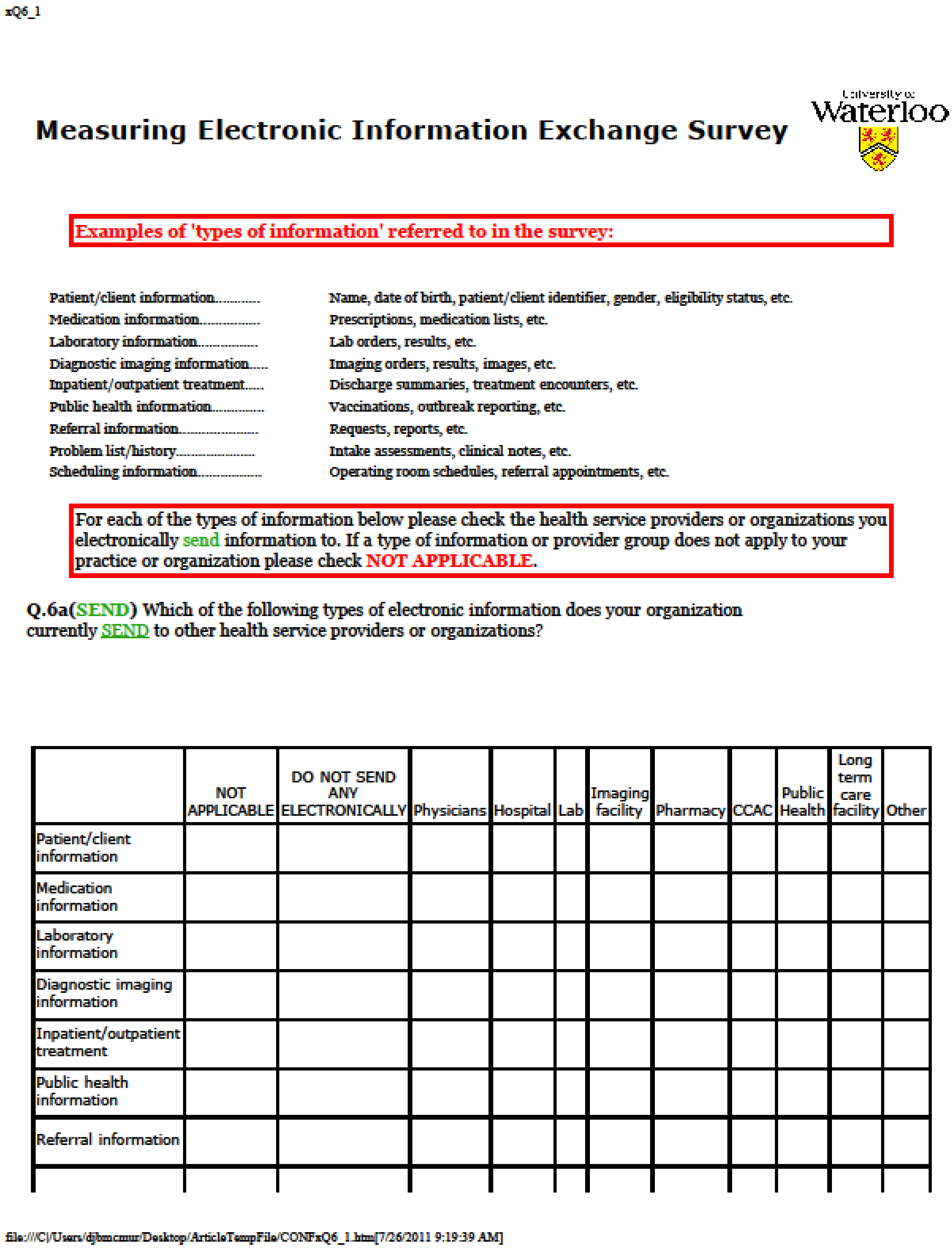

xQ6_1

Measuring Electronic Information Exchange Survey

University of Waterloo

Examples of 'types of information' referred to in the survey:

Patient/client information............	Name, date of birth, patient/client identifier, gender, eligibility status, etc.
Medication information................	Prescriptions, medication lists, etc.
Laboratory information................	Lab orders, results, etc.
Diagnostic imaging information.....	Imaging orders, results, images, etc.
Inpatient/outpatient treatment.....	Discharge summaries, treatment encounters, etc.
Public health information.............	Vaccinations, outbreak reporting, etc.
Referral information......................	Requests, reports, etc.
Problem list/history......................	Intake assessments, clinical notes, etc.
Scheduling information.................	Operating room schedules, referral appointments, etc.

For each of the types of information below please check the health service providers or organizations you electronically send information to. If a type of information or provider group does not apply to your practice or organization please check **NOT APPLICABLE.**

Q.6a(SEND) Which of the following types of electronic information does your organization currently SEND to other health service providers or organizations?

	NOT APPLICABLE	DO NOT SEND ANY ELECTRONICALLY	Physicians	Hospital	Lab	Imaging facility	Pharmacy	CCAC	Public Health	Long term care facility	Other
Patient/client information											
Medication information											
Laboratory information											
Diagnostic imaging information											
Inpatient/outpatient treatment											
Public health information											
Referral information											

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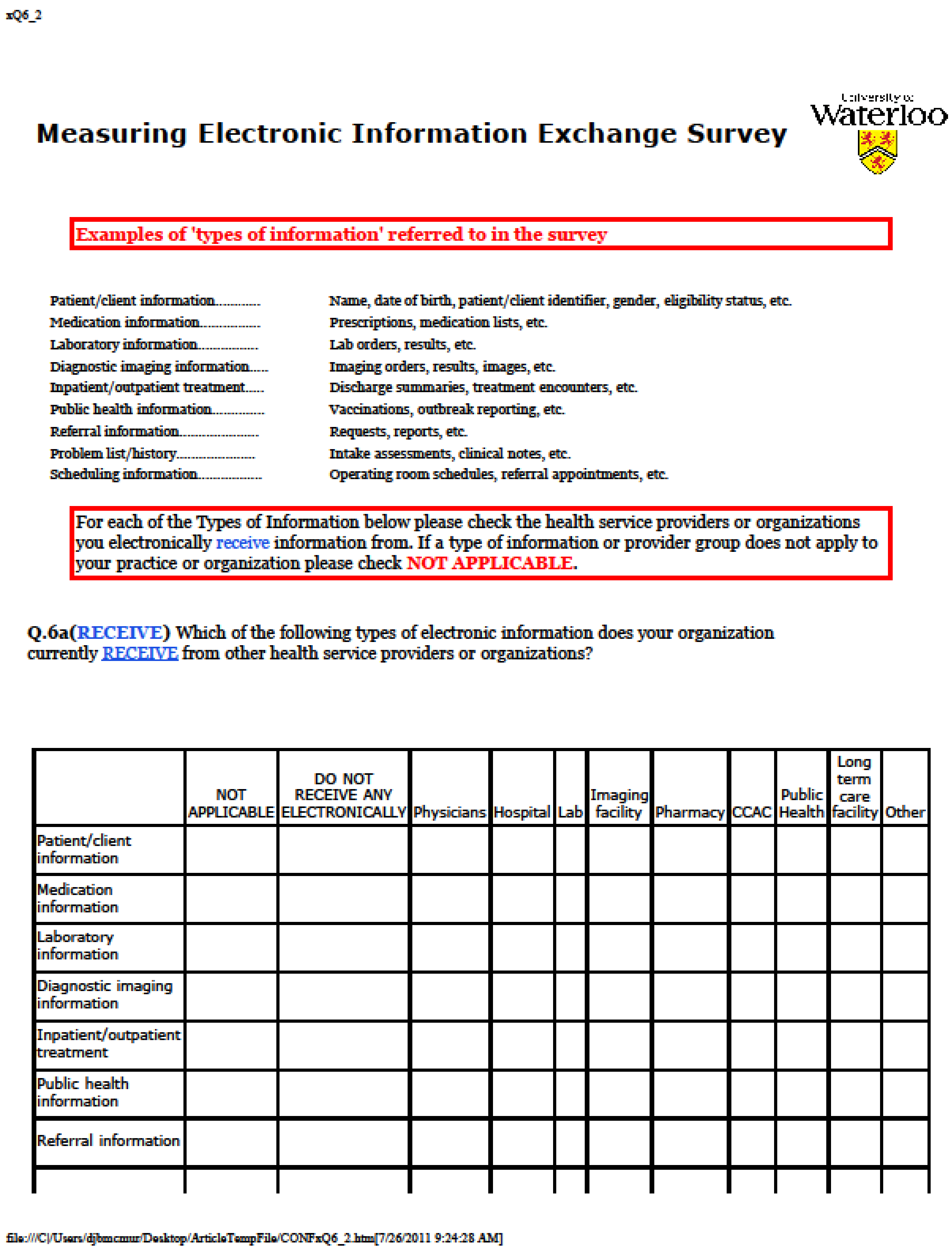

xQ6_2

Measuring Electronic Information Exchange Survey

University of Waterloo

Examples of 'types of information' referred to in the survey

Patient/client information............	Name, date of birth, patient/client identifier, gender, eligibility status, etc.
Medication information.................	Prescriptions, medication lists, etc.
Laboratory information................	Lab orders, results, etc.
Diagnostic imaging information.....	Imaging orders, results, images, etc.
Inpatient/outpatient treatment.....	Discharge summaries, treatment encounters, etc.
Public health information.............	Vaccinations, outbreak reporting, etc.
Referral information......................	Requests, reports, etc.
Problem list/history......................	Intake assessments, clinical notes, etc.
Scheduling information.................	Operating room schedules, referral appointments, etc.

For each of the Types of Information below please check the health service providers or organizations you electronically receive information from. If a type of information or provider group does not apply to your practice or organization please check NOT APPLICABLE.

Q.6a(RECEIVE) Which of the following types of electronic information does your organization currently RECEIVE from other health service providers or organizations?

	NOT APPLICABLE	DO NOT RECEIVE ANY ELECTRONICALLY	Physicians	Hospital	Lab	Imaging facility	Pharmacy	CCAC	Public Health	Long term care facility	Other
Patient/client information											
Medication information											
Laboratory information											
Diagnostic imaging information											
Inpatient/outpatient treatment											
Public health information											
Referral information											

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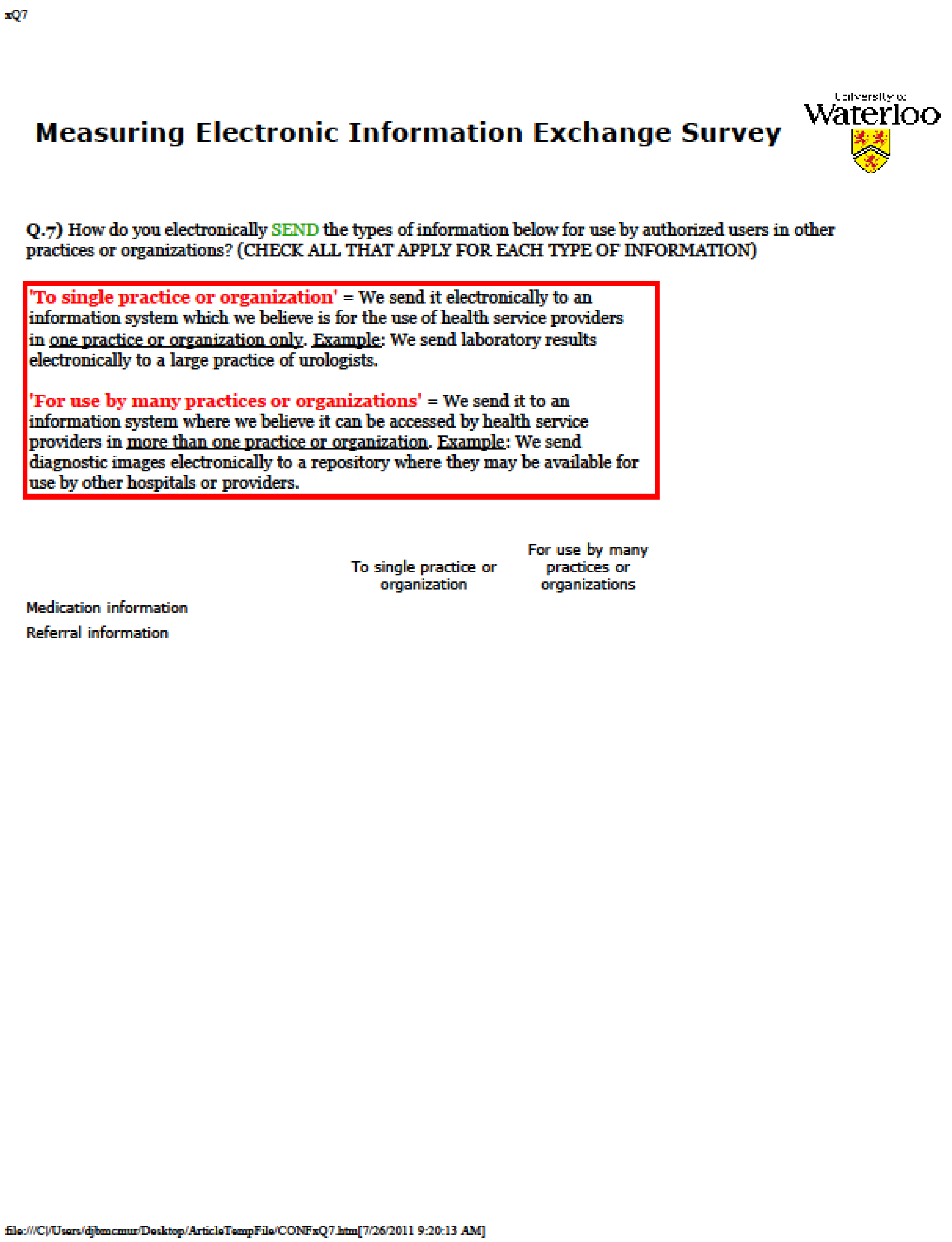

xQ7

Measuring Electronic Information Exchange Survey

University of Waterloo

Q.7) How do you electronically SEND the types of information below for use by authorized users in other practices or organizations? (CHECK ALL THAT APPLY FOR EACH TYPE OF INFORMATION)

'To single practice or organization' = We send it electronically to an information system which we believe is for the use of health service providers in one practice or organization only. Example: We send laboratory results electronically to a large practice of urologists.

'For use by many practices or organizations' = We send it to an information system where we believe it can be accessed by health service providers in more than one practice or organization. Example: We send diagnostic images electronically to a repository where they may be available for use by other hospitals or providers.

	To single practice or organization	For use by many practices or organizations
Medication information		
Referral information		

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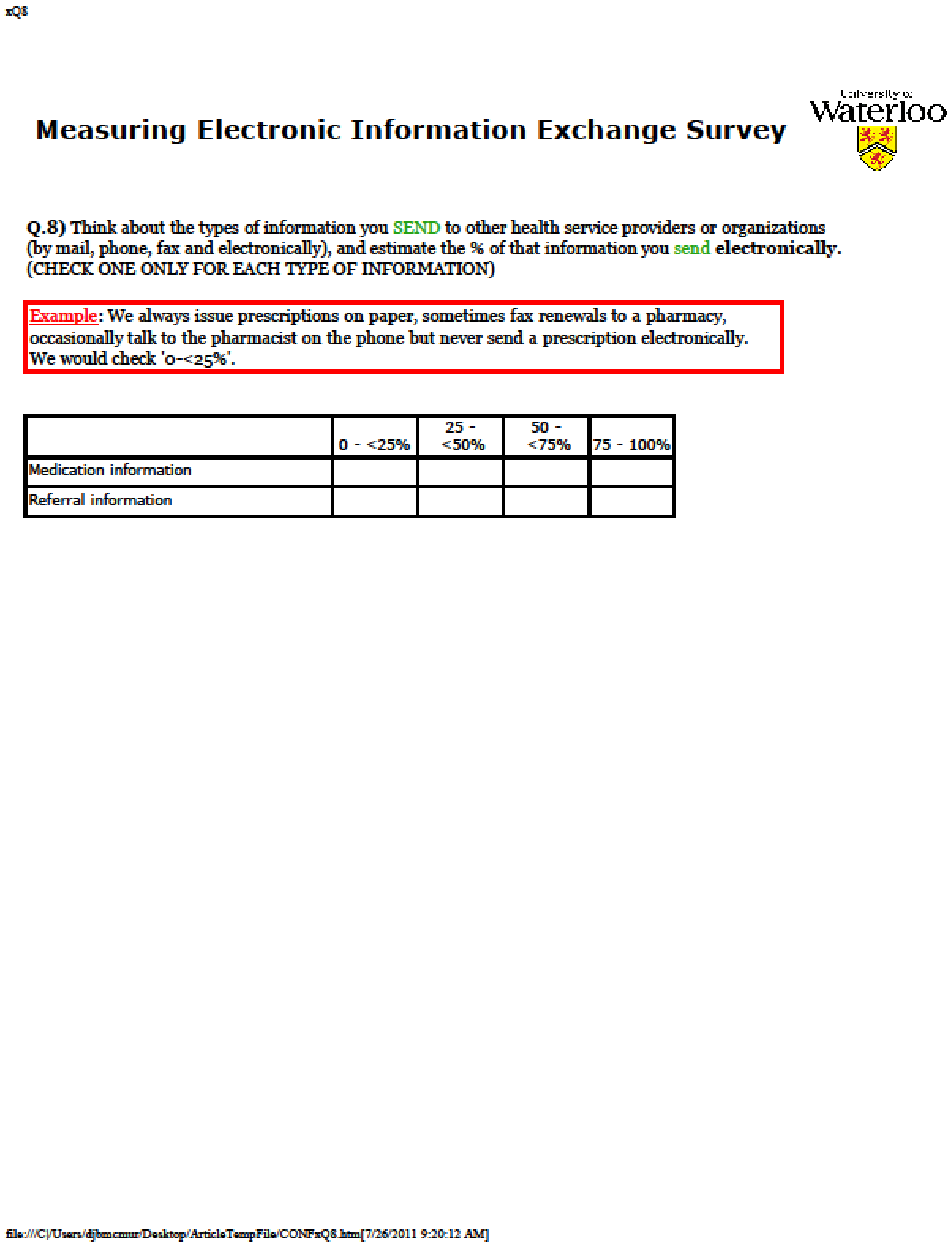

xQ8

Measuring Electronic Information Exchange Survey

University of Waterloo

Q.8) Think about the types of information you SEND to other health service providers or organizations (by mail, phone, fax and electronically), and estimate the % of that information you send **electronically.** (CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

Example: We always issue prescriptions on paper, sometimes fax renewals to a pharmacy, occasionally talk to the pharmacist on the phone but never send a prescription electronically. We would check '0-<25%'.

	0 - <25%	25 - <50%	50 - <75%	75 - 100%
Medication information				
Referral information				

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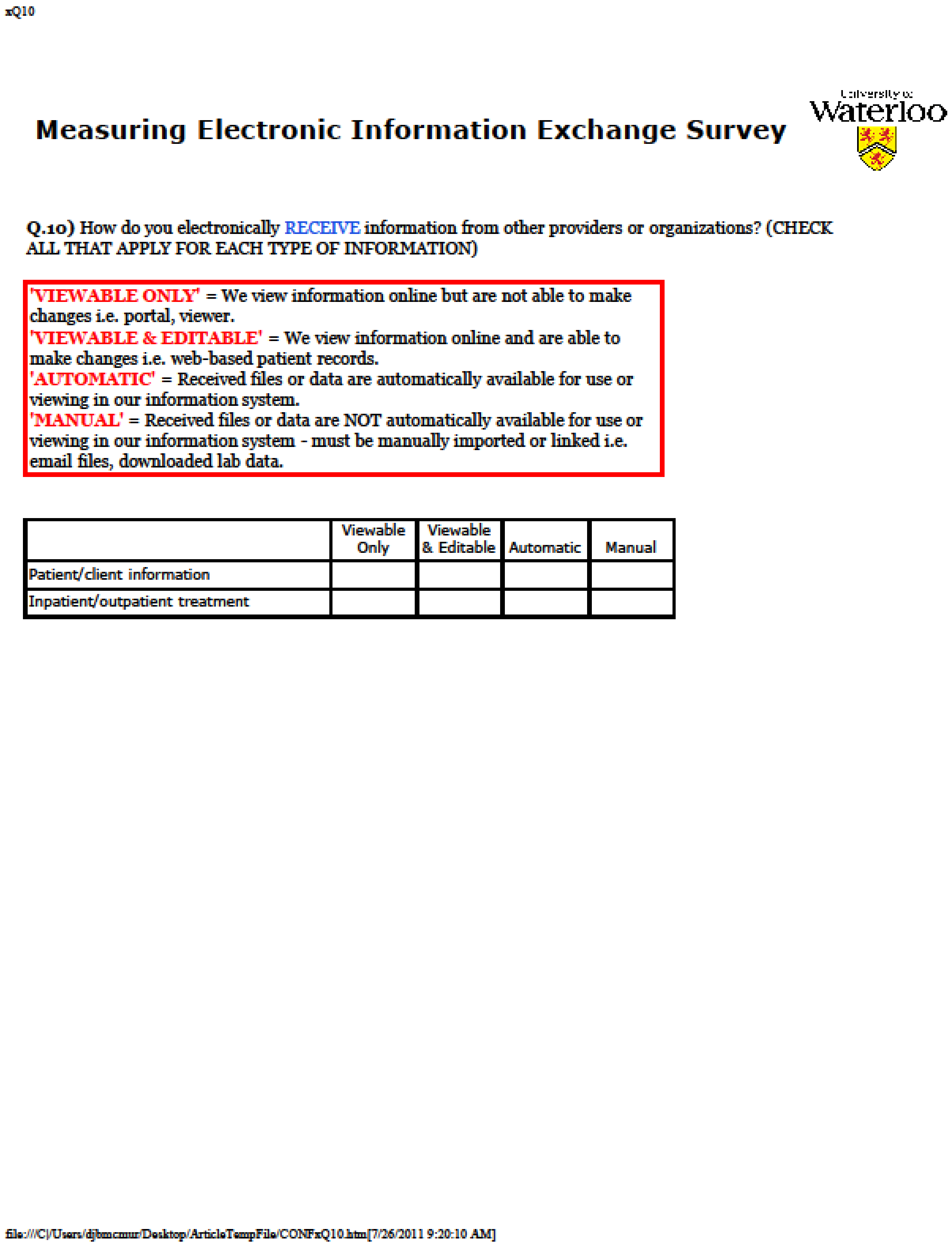
Measuring Electronic Information Exchange Survey

Q.9) Think about the number of health service providers or organizations you SEND this information to (by mail, phone, fax and electronically). To what % of them do you SEND information electronically? (CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

	0 - <25%	25 - <50%	50 - <75%	75 - 100%
Medication information				
Referral information				



xQ10

Measuring Electronic Information Exchange Survey

University of Waterloo

Q.10) How do you electronically RECEIVE information from other providers or organizations? (CHECK ALL THAT APPLY FOR EACH TYPE OF INFORMATION)

'VIEWABLE ONLY' = We view information online but are not able to make changes i.e. portal, viewer.
'VIEWABLE & EDITABLE' = We view information online and are able to make changes i.e. web-based patient records.
'AUTOMATIC' = Received files or data are automatically available for use or viewing in our information system.
'MANUAL' = Received files or data are NOT automatically available for use or viewing in our information system - must be manually imported or linked i.e. email files, downloaded lab data.

	Viewable Only	Viewable & Editable	Automatic	Manual
Patient/client information				
Inpatient/outpatient treatment				

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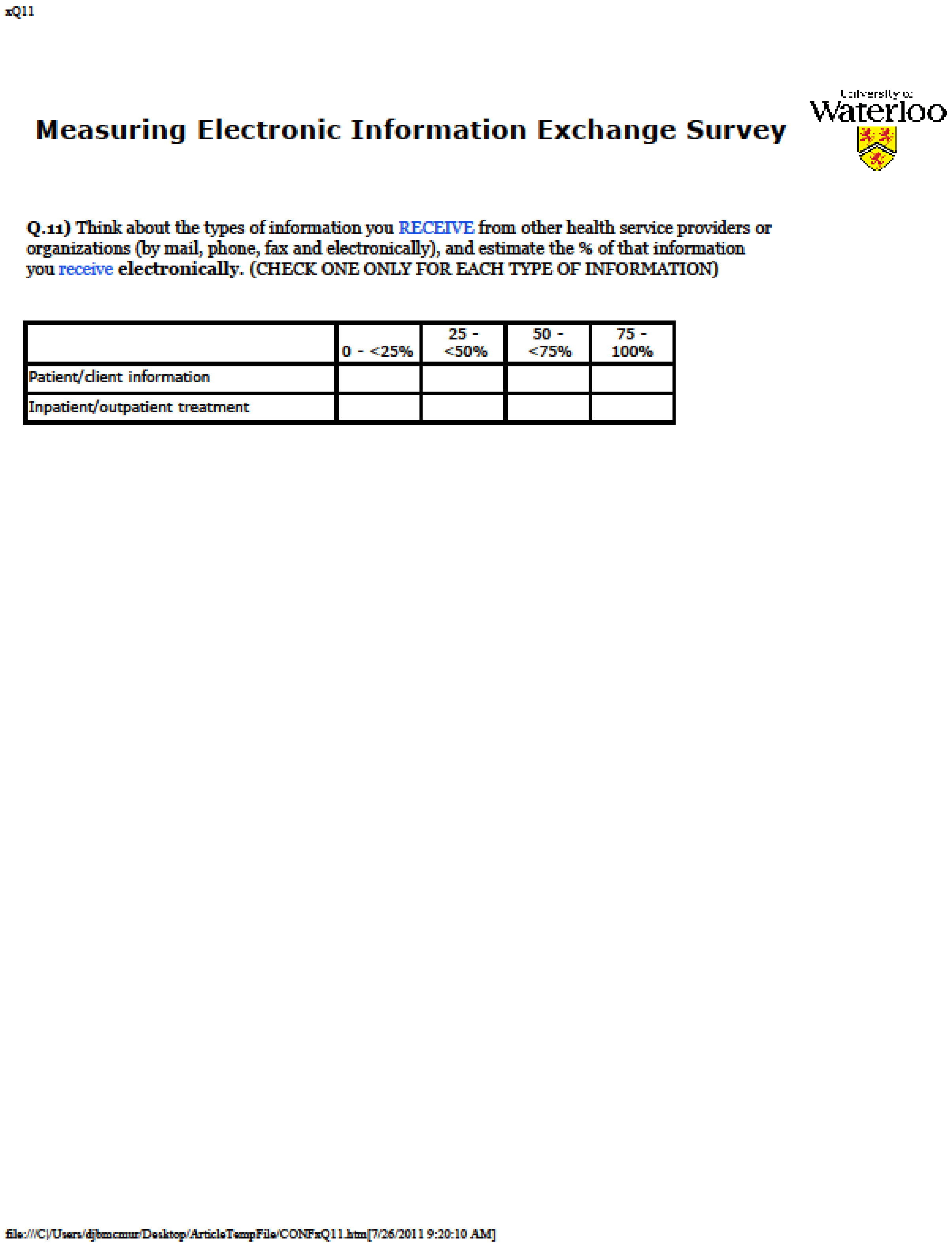

xQ11

Measuring Electronic Information Exchange Survey

University of Waterloo

Q.11) Think about the types of information you RECEIVE from other health service providers or organizations (by mail, phone, fax and electronically), and estimate the % of that information you receive electronically. (CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

	0 - <25%	25 - <50%	50 - <75%	75 - 100%
Patient/client information				
Inpatient/outpatient treatment				

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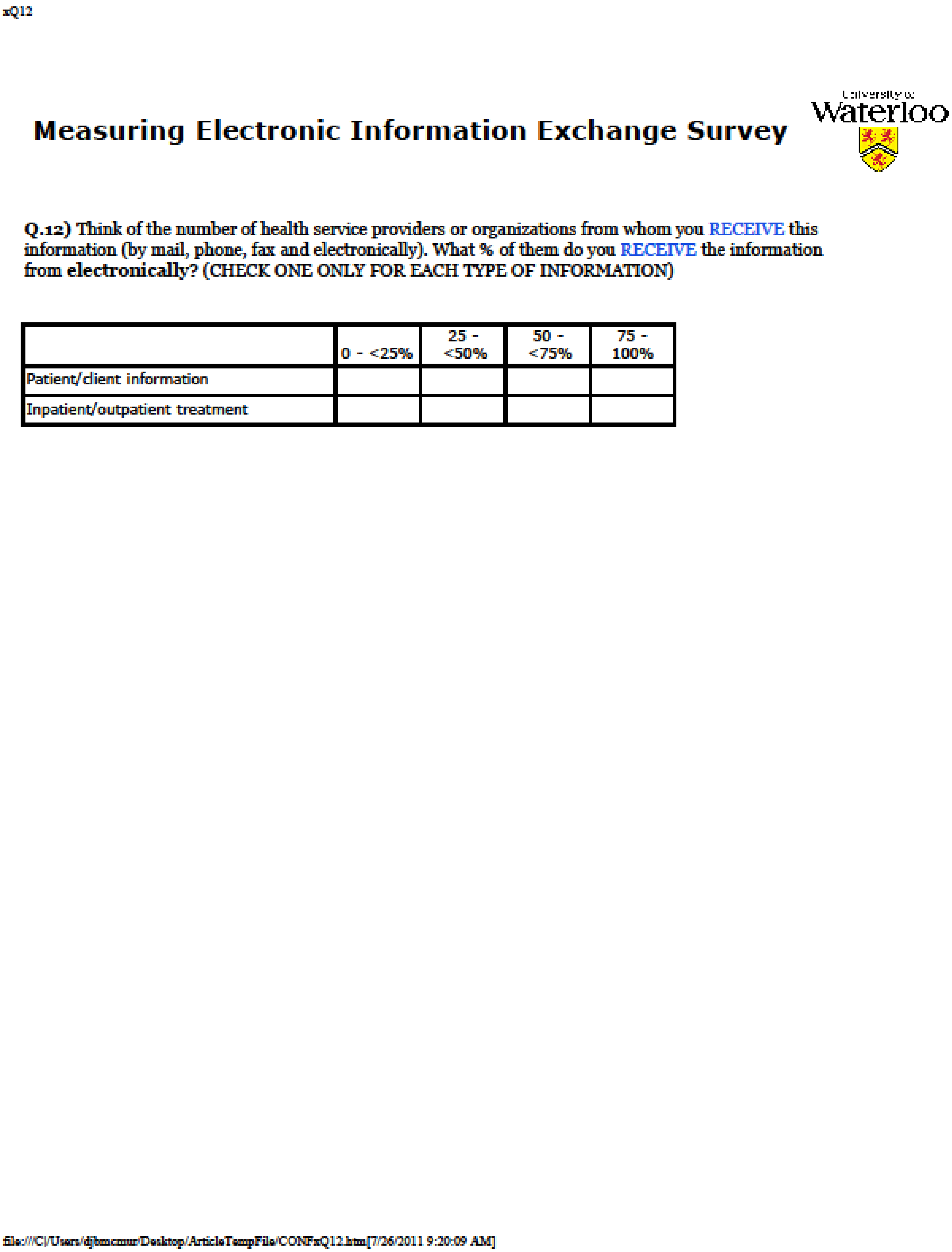

xQ12

Measuring Electronic Information Exchange Survey

Q.12) Think of the number of health service providers or organizations from whom you RECEIVE this information (by mail, phone, fax and electronically). What % of them do you RECEIVE the information from electronically? (CHECK ONE ONLY FOR EACH TYPE OF INFORMATION)

	0 - <25%	25 - <50%	50 - <75%	75 - 100%
Patient/client information				
Inpatient/outpatient treatment				

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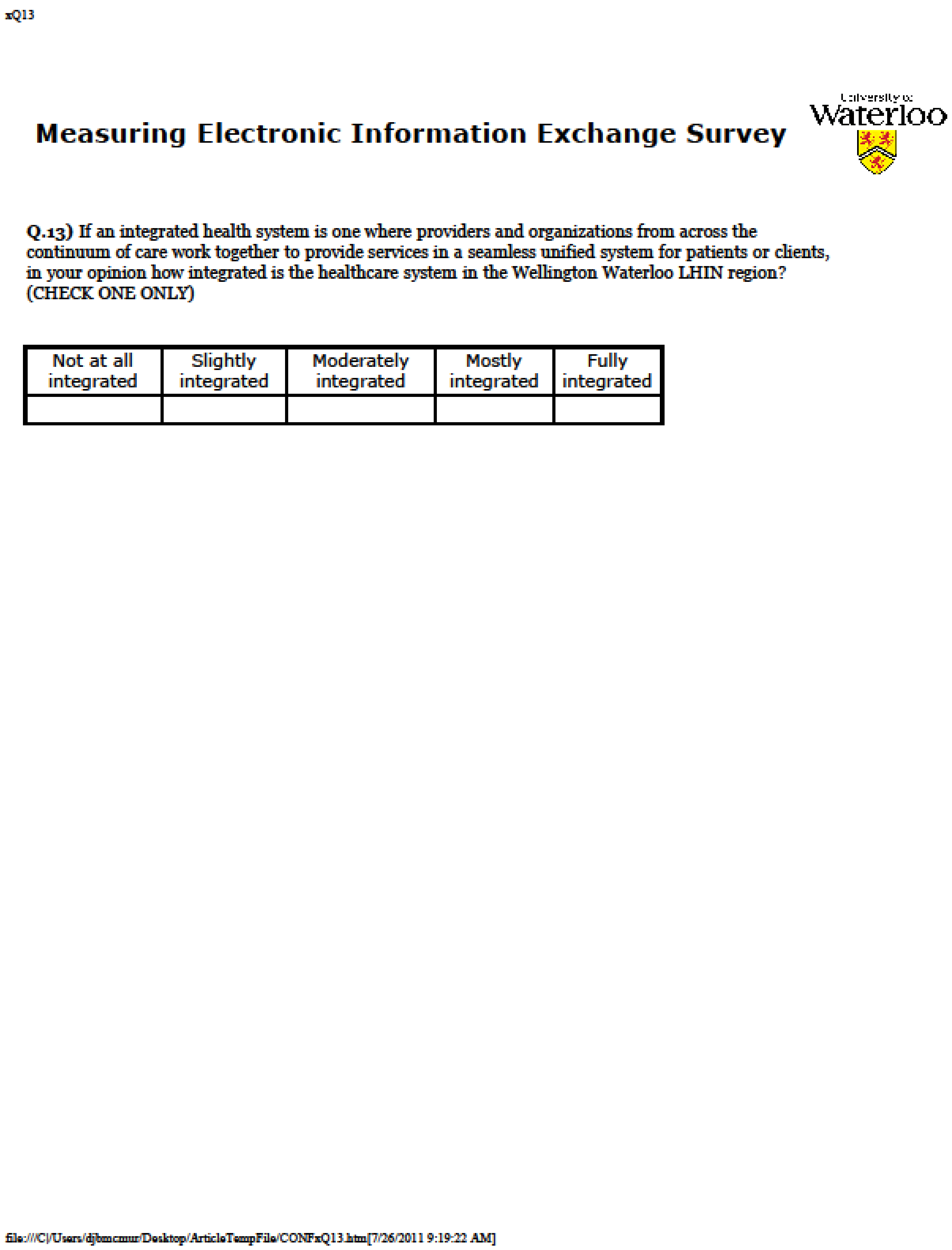
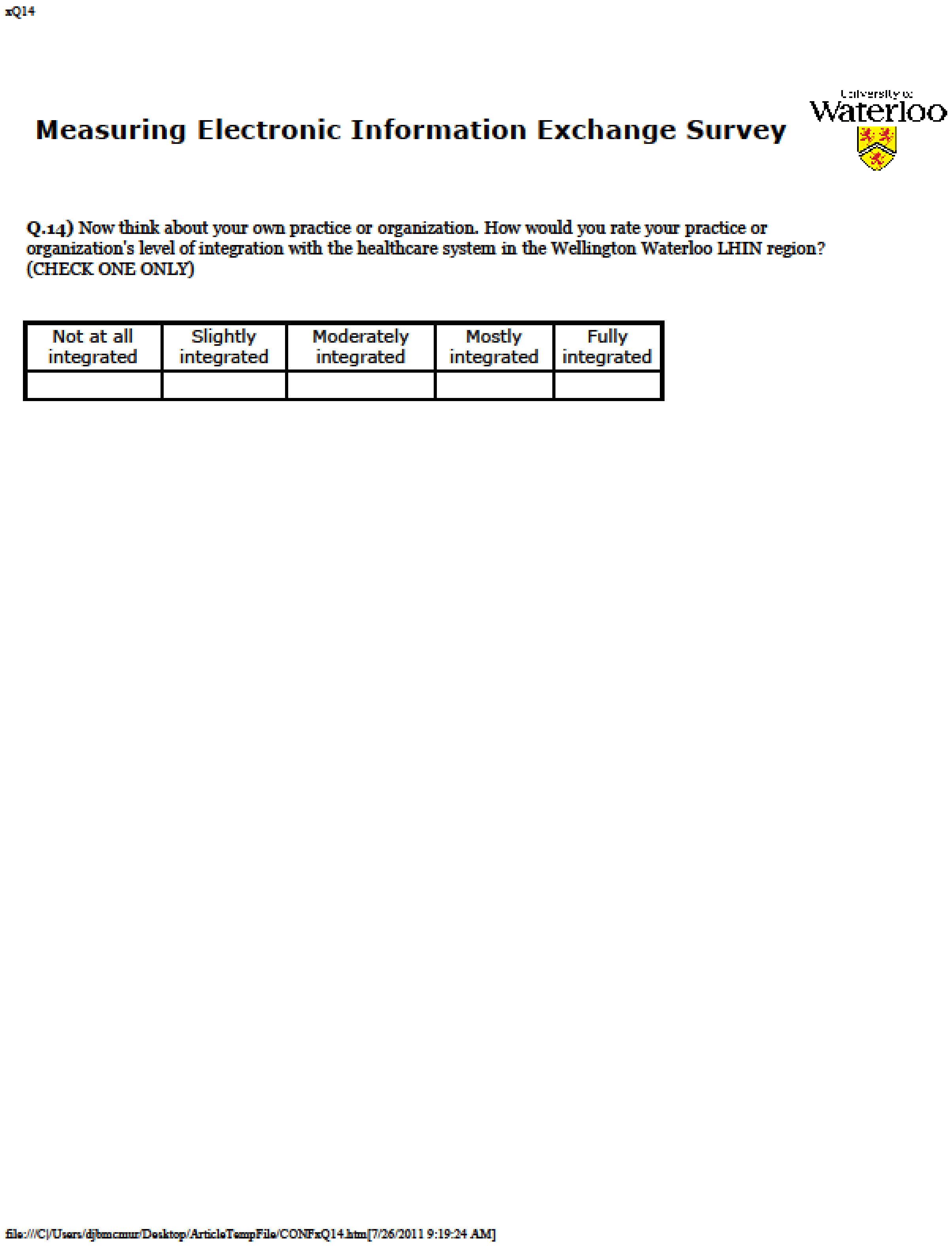


Measuring Electronic Information Exchange Survey

Q.13) If an integrated health system is one where providers and organizations from across the continuum of care work together to provide services in a seamless unified system for patients or clients, in your opinion how integrated is the healthcare system in the Wellington Waterloo LHIN region? (CHECK ONE ONLY)

Not at all integrated	Slightly integrated	Moderately integrated	Mostly integrated	Fully integrated



xQ14

Measuring Electronic Information Exchange Survey

Q.14) Now think about your own practice or organization. How would you rate your practice or organization's level of integration with the healthcare system in the Wellington Waterloo LHIN region? (CHECK ONE ONLY)

Not at all integrated	Slightly integrated	Moderately integrated	Mostly integrated	Fully integrated

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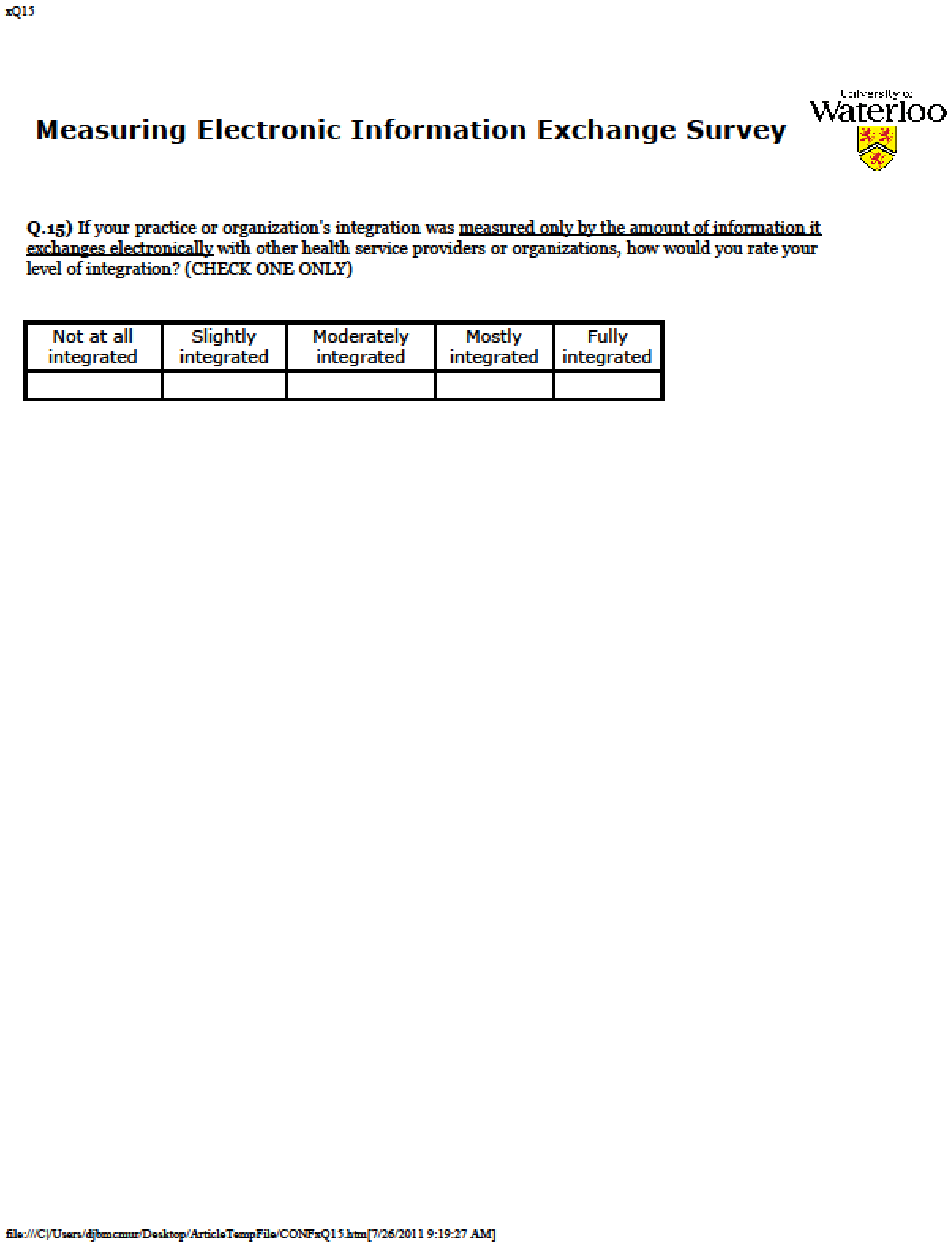

xQ15

Measuring Electronic Information Exchange Survey

Q.15) If your practice or organization's integration was measured only by the amount of information it exchanges electronically with other health service providers or organizations, how would you rate your level of integration? (CHECK ONE ONLY)

Not at all integrated	Slightly integrated	Moderately integrated	Mostly integrated	Fully integrated

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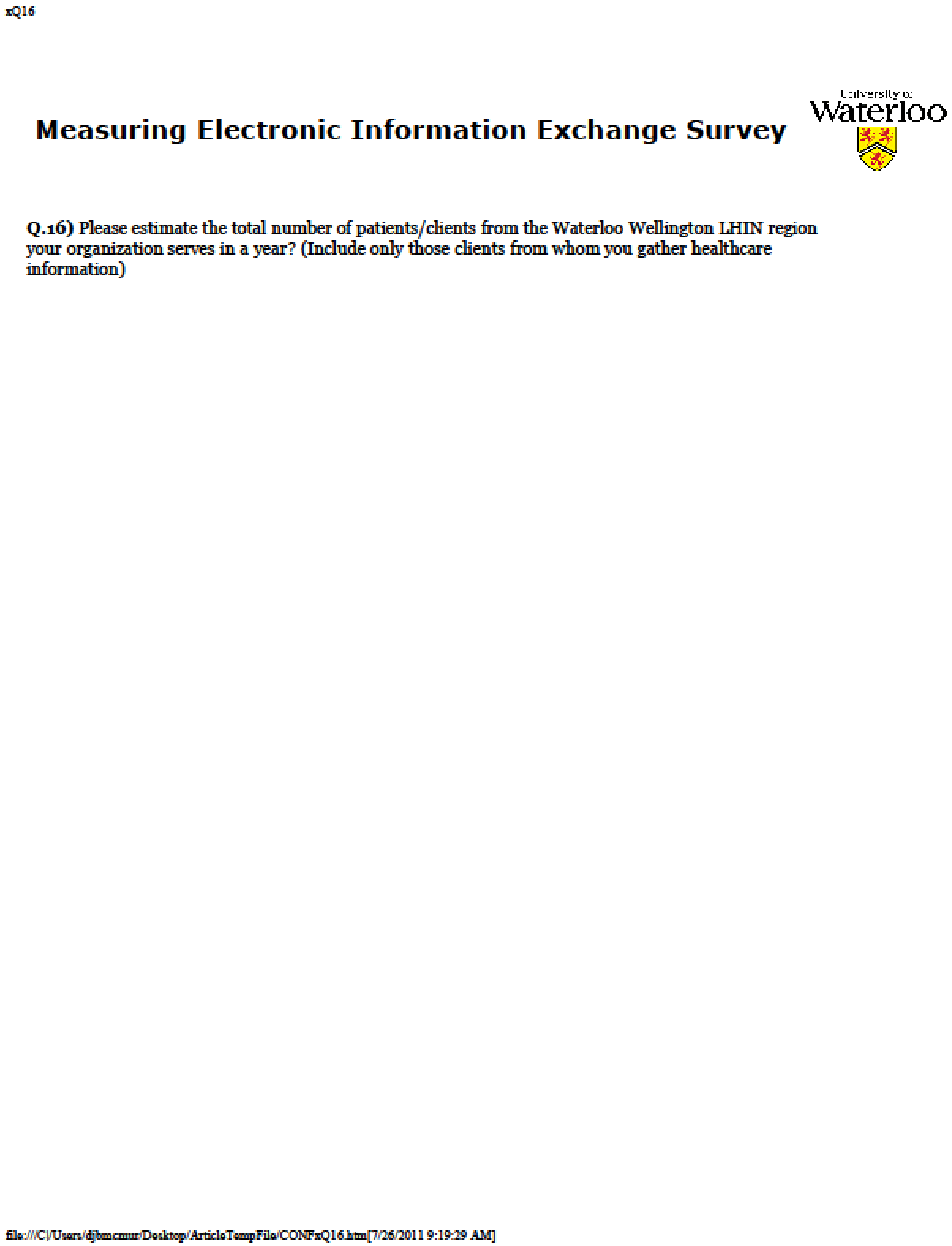
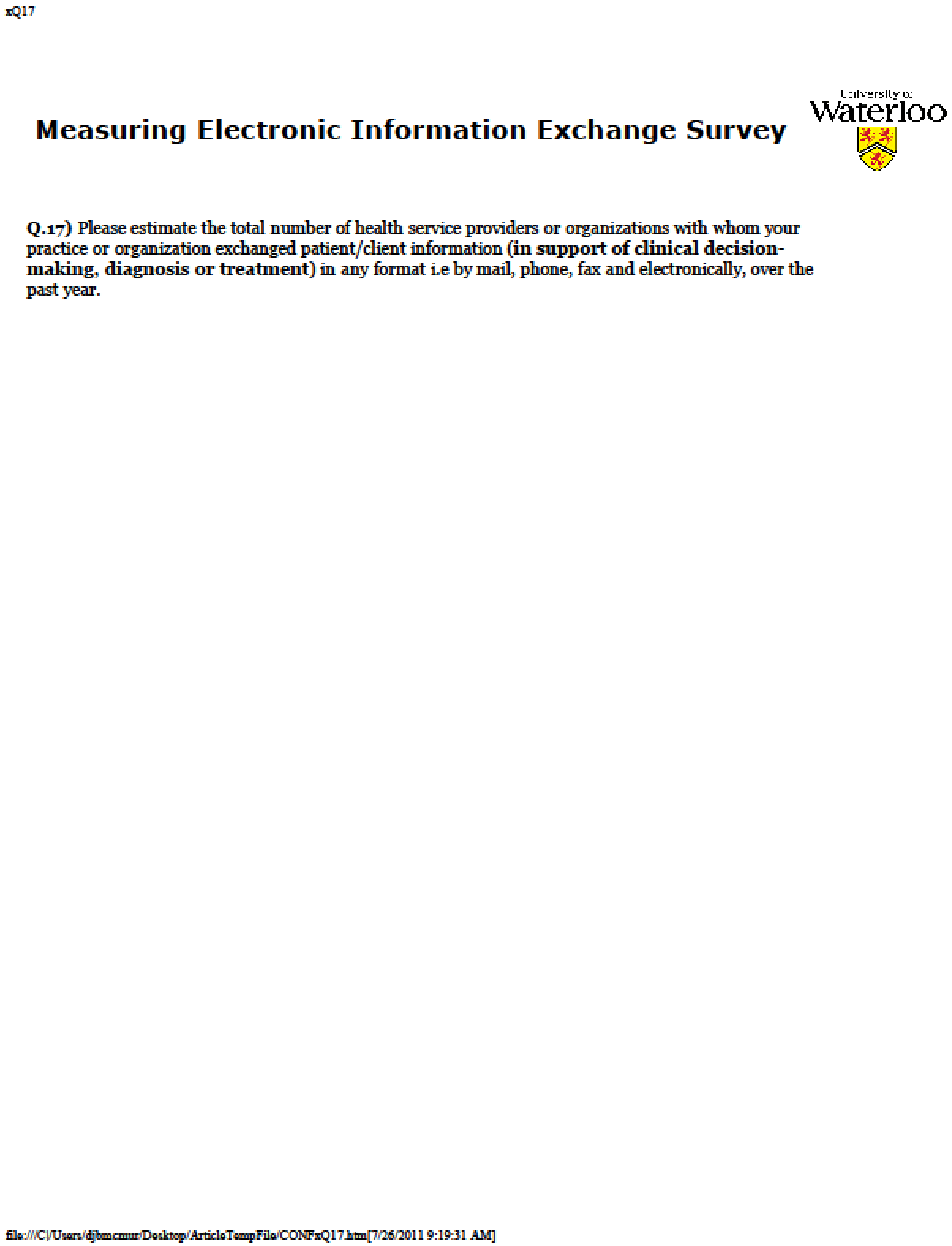


Measuring Electronic Information Exchange Survey

Q.16) Please estimate the total number of patients/clients from the Waterloo Wellington LHIN region your organization serves in a year? (Include only those clients from whom you gather healthcare information)



xQ17

Measuring Electronic Information Exchange Survey

Q.17) Please estimate the total number of health service providers or organizations with whom your practice or organization exchanged patient/client information (in support of clinical decision-making, diagnosis or treatment) in any format i.e by mail, phone, fax and electronically, over the past year.

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Measuring Electronic Information Exchange Survey

Q.18) How many locations does your practice or organization operate from in the Waterloo Wellington LHIN?

xQ19

Measuring Electronic Information Exchange Survey

Q.19) Please use this section to provide us with any comments or thoughts on the electronic exchange of patient/client information amongst health service providers in your region. Any information about your information systems or networks which might better explain your responses to the survey would also be greatly appreciated.

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Appendix I. Description of HealthEntities Included in the Regional Health System

Healthcare Service Entity Label	Description
Primary Care – Solo Practice	**Definition**: A physician in a solo practice providing primary health care to patients or groups or patients either as a sole proprietor or incorporated in some fashion. Funding is primarily on a fee for service basis. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value = 7 **Census Population in Region:** 106 **Acronyms:** GP, FP **Synonyms:** Family physician, general practitioner **Exclusions:** Physician non-members of the College of Physicians and Surgeons of Ontario or CPSO members in one of the other PrimaryCareEntity classes **sameAs** SoloPractice-PrimaryCareEntities
Primary Care – Group Practice	**Definition**: A physician or group of primary care providers such as nurse practitioners and physicians, in a group practice providing primary health care to patients or groups or patients which is not one of the other types of primary care class, as a limited liability partnership or professional corporation. Funding is primarily on a fee for service basis. **Scope:**

Healthcare Service Entity Label	**Description**
	Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value = 8 **Census Population in Region:** 6 **Acronyms:** GP, FP **Synonyms:** Family physician, general practitioner, medical group **Exclusions:** Physician non-members of the College of Physicians and Surgeons of Ontario, or CPSO members in one of the other PrimaryCareEntity classes **sameAs** GroupPractice-PrimaryCareEntities
Primary Care – Family Health Group	**Definition**: Family Health Groups (FHG) offer comprehensive primary health care services to their enrolled patients. Family Health Groups offer regular office hours plus extra After Hours blocks of office time. FHG physicians are also on call to a ministry funded Telephone Health Advisory Service (THAS) outside of regular office hours that takes phone calls from their enrolled patients. Funding is Fee-for-service plus some incentives and bonuses for services to enrolled patients. Rostering and Patient Fees (i.e. New Patient Fee) and some incentives, premiums and bonuses, chronic disease management and preventive care are paid for eligible services to enrolled patients. Additionally, physicians receive monthly comprehensive care capitation payments for all enrolled patients. (www.healthforceontario.ca) **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding.

Healthcare Service Entity Label	Description
	Examples: Derived from Q1_TypeOfOrg Value = 9 **Census Population in Region:** 6 **Acronyms:** FHG **Synonyms:** Group practice **Exclusions:** Physician non-members of the College of Physicians and Surgeons of Ontario, or CPSO members in one of the other PrimaryCareEntity classes **sameAs** FamilyHealthGroupEntities
Primary Care – Family Health Team	**Definition**: Family Health Teams are groups of health care professionals, such as physicians, nurse practitioners, nurses, social workers and dieticians who work together to provide primary care for a group of patients. They provide a wide range of services including health promotion, treatment services, chronic disease management and prevention, rehabilitation and palliative care. They are available nights and weekends to provide health advice and care so their patients do not have to go to busy hospital emergency departments for non-emergency care. They also help their patients navigate their way through the other parts of the health care system to receive the best possible care (www.healthforceontario.ca). Family health teams are funded on a blended capitation basis similar to FHOs - the corporations may be governed by a community or provider board. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=10

Healthcare Service Entity Label	Description
	Census Population in Region: 11 **Acronyms:** FHT **Synonyms:** **Exclusions:** Members in any of the other PrimaryCareEntity classes **sameAs** FamilyHealthTeamEntities
Primary Care – Family Health Network	**Definition**: Family health networks (FHNs) are groups of physicians who work as a network along with a nurse-staffed after hours telephone advisory service to provide primary care for their patients 24 hours a day, seven days a week. The networks emphasize illness prevention and comprehensive care for patients. Funding is provided on a blended capitation model which is capitation based on a defined basket of primary care services provided to enrolled patients based on age/sex of each patient. Fee-for-service paid for other services. Additionally, physicians receive monthly comprehensive care capitation payments for all enrolled patients. Rostering and Patient Fees (i.e. New Patient Fee), and bonuses, premiums and special payments are paid for services such as chronic disease management, preventative care, pre-natal care and home visits for enrolled patients, and for hospital visits, obstetrical care and palliative care for all patients. (www.healthforceontario.ca). **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=11 **Census Population in Region:** 6 **Acronyms:**

Healthcare Service Entity Label	**Description**
	FHN **Synonyms:** **Exclusions:** Members in any of the other PrimaryCareEntity classes **sameAs** FamilyHealthNetworkEntities
Primary Care – Comprehensive Care Model	**Definition**: The Comprehensive Care Model is designed specifically for solo primary care physicians. These physicians offer comprehensive primary health care services to their enrolled patients including regular office hours plus one three hour block of after-hours services per week. Like their group counterparts, CCM physicians also emphasize illness prevention for their enrolled patients. Fee-for-service plus some incentives and bonuses for services to enrolled patients. Rostering and Patient Fees (i.e. New Patient Fee) and some incentives, premiums and bonuses, chronic disease management and preventive care are paid for eligible services to enrolled patients. Additionally, physicians receive monthly comprehensive care capitation payments for all enrolled patients. (www.healthforceontario.ca) **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=12 **Census Population in Region:** 0 **Acronyms:** **Synonyms:** **Exclusions:** Members in any of the other PrimaryCareEntity classes **sameAs**

Healthcare Service Entity Label	Description
	ComprehensiveCareModelEntities
Primary Care – College Health Services	**Definition**: A not for profit entity providing primary care located within and under the governance of a college or university, and providing services exclusively to students and or their families and employees of the college or university **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=27 **Census Population in Region:** 4 **Acronyms:** SHS **Synonyms:** **Exclusions:** Members in any of the other PrimaryCareEntity classes **sameAs** CollegeHealthServicesEntities
Physician Specialist – Solo Practice	**Definition**: A physician specialist who practices in solo practice - sole proprietorship or corporation of some kind. Funding may be fee for service or an Alternative Payment Plan but funding is primarily public. They are certified by the Royal College of Physicians and Surgeons of Canada in one or more of 60 specialties or sub-specialties: Anatomical Pathology Anesthesiology Cardiac Surgery Cardiology

Healthcare Service Entity Label	Description
	Clinical Immunology and Allergy
	Clinical Pharmacology
	Community Medicine
	Critical Care Medicine (Pediatric or Adult)
	Dermatology
	Diagnostic Radiology
	Emergency Medicine
	Endocrinology and Metabolism
	Gastroenterology
	General Pathology
	General Surgery
	Geriatric Medicine
	Gynecologic Oncology
	Hematological Pathology
	Hematology
	Infectious Diseases
	Internal Medicine
	Maternal-fetal Medicine
	Medical Biochemistry
	Medical Genetics
	Medical Microbiology
	Medical Oncology
	Neonatal-Perinatal Medicine
	Nephrology
	Neurology
	Neuropathology
	Neuroradiology
	Neurosurgery
	Nuclear Medicine

Healthcare Service Entity Label	Description
	Obstetrics and Gynecology Occupational Medicine Ophthalmology Orthopedic Surgery Otolaryngology Palliative Medicine Pediatric Emergency Medicine Pediatric General Surgery Pediatric Hematology / Oncology Pediatric Radiology Pediatrics Physical Medicine and Rehabilitation Plastic Surgery Psychiatry Radiation Oncology Respirology (Adult or Pediatric) Rheumatology Thoracic Surgery Transfusion Medicine Urology Vascular Surgery **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding **Examples:** Derived from Q1_TypeOfOrg Value=13 **Census Population in Region:** 141 **Acronyms:**

Healthcare Service Entity Label	Description
	Synonyms: **Exclusions:** Physician non-members of the College of Physicians and Surgeons of Ontario, or CPSO members in one of the other SpecialistCareEntities classes **sameAs** SoloPractice-PhysicianSpecialistEntities
Physician Specialist – Group Practice	**Definition**: A group of specialists who practice together under a governance arrangement such as a limited partnership or incorporation or some kind. Funding may be fee for service or Alternative Payment Plan but the majority of revenue is public funding. They are certified by the Royal College of Physicians and Surgeons of Canada in one or more of 60 specialties or sub-specialties: Anatomical Pathology Anesthesiology Cardiac Surgery Cardiology Clinical Immunology and Allergy Clinical Pharmacology Community Medicine Critical Care Medicine (Pediatric or Adult) Dermatology Diagnostic Radiology Emergency Medicine Endocrinology and Metabolism Gastroenterology General Pathology General Surgery Geriatric Medicine Gynecologic Oncology

Healthcare Service Entity Label	Description
	Hematological Pathology
	Hematology
	Infectious Diseases
	Internal Medicine
	Maternal-fetal Medicine
	Medical Biochemistry
	Medical Genetics
	Medical Microbiology
	Medical Oncology
	Neonatal-Perinatal Medicine
	Nephrology
	Neurology
	Neuropathology
	Neuroradiology
	Neurosurgery
	Nuclear Medicine
	Obstetrics and Gynecology
	Occupational Medicine
	Ophthalmology
	Orthopedic Surgery
	Otolaryngology
	Palliative Medicine
	Pediatric Emergency Medicine
	Pediatric General Surgery
	Pediatric Hematology / Oncology
	Pediatric Radiology
	Pediatrics
	Physical Medicine and Rehabilitation
	Plastic Surgery

Healthcare Service Entity Label	**Description**
	Psychiatry Radiation Oncology Respirology (Adult or Pediatric) Rheumatology Thoracic Surgery Transfusion Medicine Urology Vascular Surgery **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=14 **Census Population in Region:** 34 **Acronyms:** **Synonyms:** **Exclusions:** Physician non-members of the College of Physicians and Surgeons of Ontario, or CPSO members in one of the other SpecialistCareEntities classes **sameAs** GroupPractice-PhysicianSpecialistEntities
Community Health Centre	**Definition**: A non-profit, community governed health organization that provides primary health care, health promotion and community development services using inter-disciplinary teams. The CHC's target hard to service populations such as refugees, and include social and non-medical determinants of health therefore staff may include allied health professionals such as social workers and mental health workers. Physicians are employees of the CHC

Healthcare Service Entity Label	**Description**
	Scope: Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** 4 **Census Population in Region:** 6 **Acronyms:** **Synonyms:** **Exclusions:** Members of other HealthEntities classes **sameAs** CommunityHealthCentreEntities
Diagnostic Imaging	**Definition**: A diagnostic imaging entity is an entity [not a hospital], licensed by the provincial government as an Independent Health Facility, and performing diagnostic imaging services such as x-ray, ultrasound, nuclear medicine, computed tomography and magnetic resonance imaging in the community. Independent Health Facility (IHF) providing diagnostic imaging services **Scope:** **Examples:** Derived from Q1_TypeOfOrg Value=16 **Census Population in Region:** 16 **Acronyms:** **Synonyms:** **Exclusions:** **sameAs** DiagnosticImagingEntities

Healthcare Service Entity Label	**Description**
Laboratory	**Definition**: A medical laboratory, licensed by the provincial government, performing tests on patients & clinical specimens for the diagnosis, treatment and prevention of disease. Community laboratory - privately or publicly owned for-profit corporate entity. Public Health Laboratory – publicly provides clinical and environmental lab testing for the prevention of disease, and protection and promotion of the public's health **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network. **Examples:** Derived from Q1_TypeOfOrg Value=15 **Census Population in Region:** 15 **Acronyms:** **Synonyms:** Lab **Exclusions:** Hospital laboratories [whose information exchange is accounted for under a "hospital" entity's response to laboratory information exchange] Members in any of the other PrimaryCareEntity classes **sameAs** LaboratoryEntities
Pharmacy	**Definition**: Pharmacy is a retail site where medications/pharmaceuticals are inventoried and dispensed. Pharmacies may be located at the same site as another health entity but has separate corporate governance structures. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and

Healthcare Service Entity Label	Description
	receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=17 **Census Population in Region:** 17 **Acronyms:** **Synonyms:** **Exclusions:** **sameAs** PharmacyEntities
Public Health Unit	**Definition**: A publicly funded [provincial, municipal, or city] health entity which administers and manages health promotion and disease prevention programs, communicable disease surveillance and control, immunization, and food inspections, under the oversight of a local Board of Health [with governance structures which are autonomous, regional/single-tier or municipal]. Oversight comes from the Public Health Agency of Canada, Public Health Ontario, and the Ministry of Health and Long Term Care. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=18 **Census Population in Region:** 2 **Acronyms:** **Synonyms:** **Exclusions:** **sameAs**

Healthcare Service Entity Label	Description
	PublicHealthUnitEntities
Long Term Care/Nursing Home	**Definition**: A long term care/nursing home entity [also referred to as a nursing home and home for the aged] is a corporation which provides residential care for patients or clients who require non-acute 24-hour nursing or supportive services on a permanent or temporary basis, across one or more locations. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=19 **Census Population in Region:** 34 **Acronyms:** **Synonyms:** “Residential Care”, “Nursing Home”, Palliative Care” **Exclusions:** TBD **sameAs** LongTermCareNursingHomeEntities
Community Counselling & Mental Health	**Definition**: A health entity providing community-based counselling, mental health, and addiction services focussed on inpatient treatment. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=24 **Census Population in Region:**

Healthcare Service Entity Label	Description
	2 **Acronyms:** **Synonyms:** **Exclusions:** Members of other HealthEntities classes **sameAs** CommunityCounsellingEntities
Pharmacy	**Definition**: Pharmacy is a retail site where medications/pharmaceuticals are inventoried and dispensed. Pharmacies may be located at the same site as another health entity but has separate corporate governance structures. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=17 **Census Population in Region:** 98 **Acronyms:** **Synonyms:** Drug store, chemist, pharmacy **Exclusions:** Online pharmacies, hospital pharmacies, in-clinic dispensaries unless under separate corporate control from the clinic **sameAs** PharmacyEntities
Sport Medicine	**Definition**: Sport medicine clinics are stand-alone multi-disciplinary sports medicine treatment and rehabilitation clinics which may have publicly funded revenue [generally through the billing and oversight

Healthcare Service Entity Label	**Description**
	of an on-site sports medicine physician] **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=23 **Census Population in Region:** 3 **Acronyms:** **Synonyms:** **Exclusions:** Physiotherapy clinics, massage therapy clinics, exercise clinics **sameAs** SportMedicineClinicEntities
Community Treatment Services	**Definition**: Treatment services providers or organizations contracted by the CCAC and receiving public funding to deliver their clinical treatment services in the patient's community or home. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Visiting nurse programs, physiotherapists, occupational therapists **Census Population in Region:** 16 **Acronyms:** NA **Synonyms:** **Exclusions:**

Healthcare Service Entity Label	**Description**
	Community-based treatment services/service providers not contracted by the CCAC or employed in a publicly funded health services organization. Includes independent physiotherapists, occupational therapists, massage therapists etc. **sameAs** TreatmentServicesEntities
Hospital – Teaching/Academic	**Definition**: Teaching hospitals are those acute and paediatric hospitals that have membership in the Council of Academic Hospitals of Ontario. They provide highly complex care, are affiliated with a medical or health sciences school and have significant research activity and post-graduate training **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding **Examples:** Derived from Q1_TypeOfOrg Value=1 **Census Population in Region:** 6 **Acronyms:** **Synonyms:** **Exclusions:** Other HospitalEntities **sameAs** TeachingHospitalEntities
Hospital - Community	**Definition**: Those hospital entities which are not teaching, small, or CCC/mental health **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and

Healthcare Service Entity Label	Description
	receiving provincial health ministry public funding **Examples:** Derived from Q1_TypeOfOrg Value=2 **Census Population in Region:** 4 **Acronyms:** **Synonyms:** **Exclusions:** Other HospitalEntities **sameAs** CommunityHospitalEntities
Hospital – Small/Rural	**Definition**: A small hospital is defined by size, isolation and geographic location, and by inpatient weighted cases. A small hospital completes less than or equal to 4000 weighted cases in a year. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding **Examples:** Derived from Q1_TypeOfOrg Value=3 **Census Population in Region:** 2 **Acronyms:** **Synonyms:** **Exclusions:** Other HospitalEntities **sameAs** SmallHospitalEntities
Hospital – Complex Continuing	**Definition**:

Healthcare Service Entity Label	Description
Care/Rehabilitation	Complex continuing care and rehabilitation hospitals are facilities whose primary focus is to specialize in rehabilitation services or the long term care of patients with complex needs which require specialized but non-acute inpatient care and outpatient care. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding **Examples:** Derived from Q1_TypeOfOrg Value=4 **Census Population in Region:** 1 **Acronyms:** **Synonyms:** **Exclusions:** Multi-site hospitals were CCC or rehab are included in the services but are subsumed by the acute care activities and services to patients, and thus are included in the teaching, small or community hospital classes Members in any of the other HospitalEntities classes **sameAs** CCC/RehabHospitalEntities
Hospital – Mental Health	**Definition**: Mental health hospitals are those hospitals for which the diagnosis and treatment of psychiatric and mental illness are the primary source of funding and focus of care. **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=5 **Census Population in Region:**

Healthcare Service Entity Label	Description
	1 **Acronyms:** **Synonyms:** **Exclusions:** Members in any of the other HospitalEntities classes including those which provide inpatient or outpatient mental health care as supplementary to their schedule of services **sameAs** MentalHealthHospitalEntities
Government Department	**Definition**: Primary care type services, fully funded by the federal government, and delivered by primary care providers (generally physicians or nurses) **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=26 **Census Population in Region:** 2 **Acronyms:** EMT **Synonyms:** **Exclusions:** Members in any of the other HealthEntities classes **sameAs** GovernmentDepartmentEntities
Emergency Medical Services	**Definition**: An emergency medical services entity is an organization or corporate entity, funded primarily from public sources, which provides first response for medical emergencies. Pre-hospital care

	initiatives and medical oversight is provided through the Centre for Paramedic Education and Research, Hamilton Health Sciences (http://guelph.ca/living.cfm?subCatID=2121&smocid=2694) **Scope:** Providing services at least within the regional geographic boundaries of the [name withheld] Local Health Integration Network and receiving provincial health ministry public funding. **Examples:** Derived from Q1_TypeOfOrg Value=28 **Census Population in Region:** 2 **Acronyms:** **Synonyms:** Ambulance services, land ambulance **Exclusions:** Members in any of the other HealthEntities classes **sameAs** EmergencyMedicalServicesEntities

Appendix J. Aggregate Regional System eHIE Numerator Raw Data (Survey Q 7-12)

Question 7 (n=182)	For use by **single** practice/organization		For use by **many** practices/organizations	
Electronically **sends** [Type] of information to a single practice or organization? (n=181)	Count	Freq.(%)	Count	Freq.(%)
Patient/client	63	34.8	10	5.5
Medication	42	23.2	4	2.2
Laboratory	24	13.3	7	3.9
Diagnostic imaging	20	11.0	6	3.3
Inpatient/outpatient treatment	14	7.7	1	0.6
Public health	15	8.3	2	1.1
Referral	24	13.3	3	1.7
Problem list/history	26	14.4	4	2.2
Scheduling	11	6.1	2	1.1

Question 8 (n=182)	0 to <25%		25 to <50%		50 to <75%		75 to 100%	
What percentage of [Type] information do you **send** electronically?	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)
Patient/client (n=71)	27	38.0	11	15.5	12	16.9	21	29.6
Medication (n=45)	14	31.1	8	17.8	6	13.3	17	37.8
Laboratory (n=28)	11	39.3	2	7.1	4	14.3	11	39.3
Diagnostic imaging (n=23)	9	39.1	1	4.3	2	8.7	11	47.8
Inpatient/outpatient treatment (n=15)	5	33.3	1	6.7	2	13.3	7	46.7
Public health (n=16)	4	25.0	3	18.8	1	6.3	8	50.0
Referral (n=28)	9	32.1	3	10.7	4	14.3	12	42.9
Problem list/history (n=30)	13	43.3	2	6.7	3	10.0	12	40.0
Scheduling (n=13)	8	61.5	1	7.7	1	7.7	3	23.1

Question 9 (n=182)	0 to <25%		25 to <50%		50 to <75%		75 to 100%	
What percentage health service providers do you **send** [type] information to electronically?	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)
Patient/client (n=71)	28	39.4	8	11.3	12	16.9	23	32.4
Medication (n=45)	13	28.9	7	15.6	9	20.0	16	35.6
Laboratory (n=28)	7	25.0	5	17.9	7	25.0	9	32.1
Diagnostic imaging (n=23)	6	26.1	3	13.0	5	21.7	9	39.1
Inpatient/outpatient treatment (n=15)	5	33.3	1	6.7	1	6.7	8	53.3
Public health (n=16)	5	31.3	1	6.3	3	18.8	7	43.8
Referral (n=28)	9	31.0	4	13.8	3	10.3	13	44.8
Problem list/history (n=30)	13	40.6	3	9.4	3	9.4	13	40.6
Scheduling (n=13)	9	69.2	1	7.7	0	0.0	3	23.1

Question 10 (n=182)	Viewable		Viewable & Editable		Automatic		Manual	
How do you **receive** [Type] information from other providers or organizations?	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)
Patient/client (n=65)	26	40	9	13.8	18	27.7	21	32.3
Medication (n=46)	18	39.1	7	15.2	14	30.4	15	32.6
Laboratory (n=58)	27	46.6	4	7.0	20	35.1	24	42.1
Diagnostic imaging (n=45)	22	48.9	5	11.1	14	31.1	17	37.8
Inpatient/outpatient treatment (n=30)	12	40.0	3	10.0	6	20.0	10	33.3
Public health (n=24)	15	62.5	0	0.0	3	13.0	8	34.8
Referral (n=37)	14	37.8	3	8.1	9	24.3	15	40.5
Problem list/history (n=29)	9	31.0	5	17.2	3	10.3	12	41.4
Scheduling (n=14)	5	35.7	4	28.6	2	14.3	5	35.7

Question 11 (n=182)	0 to <25%		25 to <50%		50 to <75%		75 to 100%	
What percentage of [Type] information do you **receive** electronically?	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)
Patient/client (n=65)	25	38.5	14	21.5	10	15.4	16	24.6
Medication (n=46)	20	43.5	6	13.0	9	19.6	11	23.9
Laboratory (n=56)	19	33.9	6	10.7	5	8.9	26	46.4
Diagnostic imaging (n=45)	14	31.1	6	13.3	8	17.8	17	37.8
Inpatient/outpatient treatment (n=29)	13	44.8	3	10.3	3	10.3	10	34.5
Public health (n=24)	8	33.3	2	8.3	5	20.8	9	37.5
Referral (n=35)	11	31.4	5	14.3	4	11.4	15	42.9
Problem list/history (n=29)	13	44.8	2	6.9	4	13.8	10	34.5
Scheduling (n=13)	7	53.8	3	23.1	0	0.0	3	23.1

Question 12 (n=182)	0 to <25%		25 to <50%		50 to <75%		75 to 100%	
What percentage of health service providers do you **receive** [Type] information from electronically?	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)	Count	Freq. (%)
Patient/client (n=65)	27	42.9	15	23.8	6	9.5	15	23.8
Medication (n=46)	19	42.2	9	20.0	4	8.9	13	28.9
Laboratory (n=56)	22	39.3	6	10.7	7	12.5	21	37.5
Diagnostic imaging (n=45)	17	37.8	6	13.3	7	15.6	15	33.3
Inpatient/outpatient treatment (n=29)	12	41.4	5	17.2	3	10.3	9	31.0
Public health (n=24)	6	26.1	6	26.1	3	13.0	8	34.8
Referral (n=35)	10	28.6	7	20.0	4	11.4	14	40.0
Problem list/history (n=29)	13	46.4	6	21.4	2	7.1	7	25.0
Scheduling (n=13)	7	53.8	3	23.1	1	7.7	2	15.4

Appendix K. OHA eHealth Applications List[8]

Dictation with Speech Recognition
Dictation
Patient Scheduling
Clinical Data Repository
Order Entry (Includes Order Communications)
Electronic Patient Record (EPR)
Pharmacy Management System
Admission Discharge Transfer
(ADT)/Registration
OR Scheduling
Interface Engines
Microbiology
Browser
Provider Registry
Drug Information System
Client Registry
Radiology Information System
Diagnostic Imaging (DI) System
Laboratory Information System
DI/PACS Data Repository
Blood Bank
Anatomical Pathology
Nursing Documentation
In-House Transcription
Chart Tracking/Locator
Materials Management
Document Management - HIM
Operating Room (Surgery) - Pre-Operative
Operating Room (Surgery) - Peri-Operative
Abstracting
Emergency Department Information System

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[8] Source: Ontario Hospital Association. (2010). *Clinical Capabilities and eHealth Adoption: Technologies and Applications Survey*. Used with Permission, OHA.

Operating Room (Surgery) - Post-Operative
Virtual Terminal (VT) (e.g. Citrix)
Synoptic Reporting
Specimen Bar Coding
Computerized Practitioner Order Entry (CPOE)
Electronic Medication Administration Record (EMAR)
eReferral System
Release of Information Tracking
Physician Documentation
Data Warehouse Management
Web Development Tool
Case Cart Management
Fixed Asset Equipment Tracking
Pharmacy Bar Coding
Materials Management Bar Coding
Patient Registration Bar Coding
Radiology Bar Coding
Wireless Local Area Network (WLAN)
Encoder
Cardiology Information System
Respiratory Care Information System
Business Process Management
Single Sign-On
Outsourced Transcription
Genetics Testing
Patient Bar Coding
Nursing Bar Coding
Computers on Wheels (COWS)
RFID - Patient Tracking