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An Economic Evaluation of a Novel Electronic Discharge Communication Tool

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An Economic Evaluation of a Novel Electronic Discharge Communication Tool

by

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Abstract

The transition from acute-care hospitalization to community-based care is a vulnerable period in healthcare delivery due to potential for post-discharge adverse events. This vulnerability has been attributed to the miscommunication between acute and community-based physicians, as current systems do not control for legibility, completeness or timeliness of the discharge summary. One potential approach to bridging this communication gap is the use of electronic discharge communication tools, which can be designed to ensure the consistent and timely transfer of information. Given the limited healthcare budget, the costs and benefits of these tools should be considered prior to large scale implementation. Thus, the goal of this thesis is to establish the cost-effectiveness of electronic discharge communication tools. To achieve this, a systematic review of published literature was conducted (Chapter 2), a prospective economic evaluation of a novel electronic discharge communication tool was completed (Chapter 3), and policy options/considerations were presented (Chapter 4).

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List of Abbreviations

AC	Ambulatory Care
AHS	Alberta Health Services
CACS	Comprehensive Ambulatory Classification System
CBA	Cost-Benefit Analysis
CEA	Cost-Effectiveness Analysis
CHEC	Consensus Health Economic Criteria list
CIHI	Canadian Institute for Health Information
CIHR	Canadian Institute for Health Research
CMG	Case Mix Grouper
CND	Canadian Dollars
CONSORT	Consolidated Standards of Reporting Trials
CUA	Cost-Utility Analysis
DAD	Discharge Abstract Database
DIN	Drug Identification Number
DNPV	Dynamic Net Present Value
ED	Emergency Department
eDCT	Electronic Discharge Communication Tool
EMBASE	Excerpta Medica Database
HUI-3	Health Utilities Index Mark 3
ICER	Incremental Cost-Effectiveness Ratio
IQR	Inter-Quartile Range
LOS	Length of Stay
MeSH	Medical Subject Heading
MTU	Medical Teaching Unit
NACRS	National Ambulatory Care Reporting System
NHSEED	National Health Services Economic Evaluation Database
PIN	Pharmaceutical Information Network
QALY	Quality Adjusted Life Year
RIW	Resource Intensity Weight
SD	Standard Deviation
USD	United States Dollars
W21C	Ward of the 21st Century
κ	Kappa Statistic

Chapter One: Background

1.1 Introduction:

1.1.1 Patient Discharge Journey:

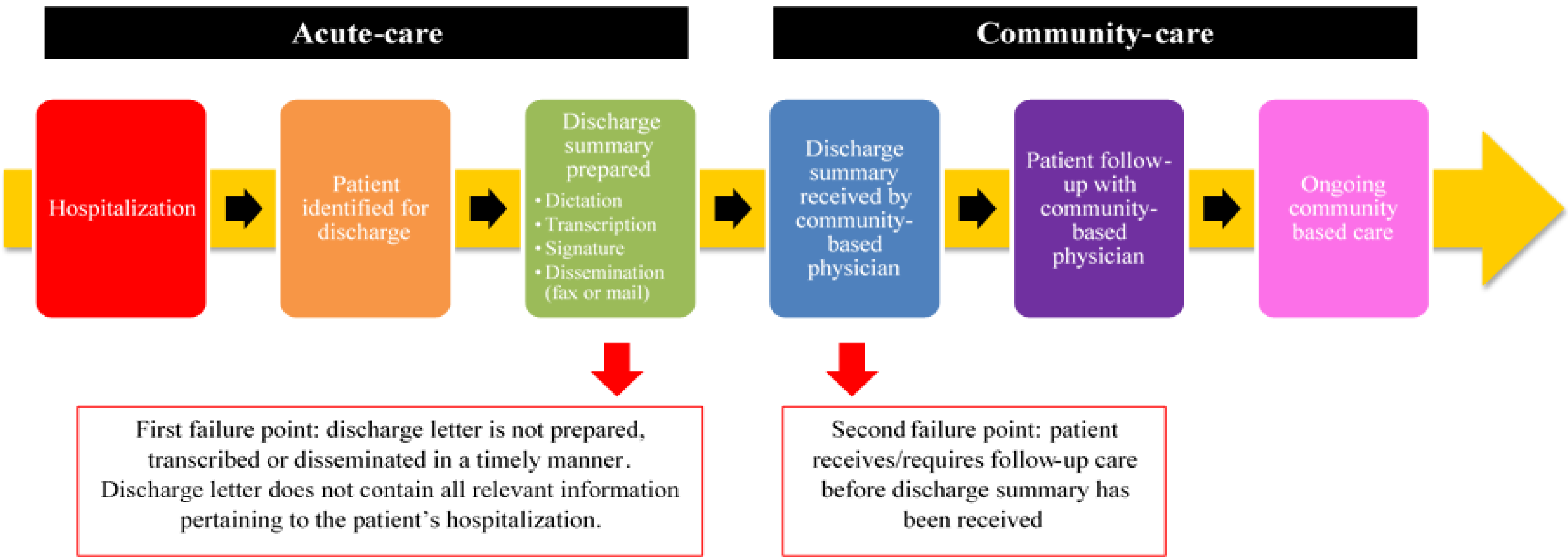
When a patient is hospitalized, their usual care pathway is: 1) the patient is admitted to the hospital where they are cared for by a multi-disciplinary team including physicians and nurses; 2) when the patient is well enough to return home, the care team prepares the patient for discharge; 3) the patient then returns home and their care is transferred to a community based physician (Figure 1). At the point of discharge, a discharge summary is prepared by part of the in-hospital care team, usually a physician either by hand or using a dictation tool. This note summarizes the reason behind the patient's hospitalization, and outlines the patient's future care plan. Once complete, the note is signed by a physician and sent to the primary care physician using fax or mail systems. Current systems do not control for legibility, completeness or timeliness of the discharge summary.

1.1.2 Transitioning from Acute-care to Community-care:

The transition from acute-care hospitalization to community-based care is a vulnerable period in healthcare delivery due to potential for post-discharge adverse events. Two Canadian studies estimated that the incidence of adverse events during the post-discharge period is between 19 and 23% at 2-5 weeks post discharge(1, 2). Of these events, 21% of patients required additional physician visits, 17% required hospital readmission, and 12% presented to the emergency department(1-3). These outcomes constitute costly, avoidable resource use and suggest that there is considerable potential for health system improvement.

The vulnerability of this transition has been attributed to three main factors that occur primarily at two points in the care pathway (Figure 1). These three factors are all related to miscommunication between in-hospital and community-based physicians(4). First, failure to reconcile medication discrepancies at the time of discharge can lead to both patient and provider confusion(4). Thus, primary care physicians may propose an inappropriate treatment plan, and an adverse drug reaction may occur. Second, the patient and/or family may be given the responsibility of relaying essential information to the primary care physician(4). This can be particularly problematic if the information is presented poorly (too rapidly, verbal only, etc.) or if the patient has low literacy or low health literacy(4-6). Finally, if the discharge letter is not disseminated in a timely manner or there is failure to transmit the letter, the primary care provider will be missing crucial information regarding the hospital stay and treatment plan of the patient(4). One systematic review noted that time from discharge to receipt of the discharge summary by the primary care physician could be as long as 106 days(7). Thus, primary care physicians frequently do not have a discharge summary available at the first post-discharge appointment; estimates report this occurs in up to 75% of cases(4, 8-10). All three of these common miscommunications negatively impact the continuity of care, result in the primary care physician being unsure of how to proceed and compromise patient care and safety.

Figure 1: Care Pathway from Admission to Community Care



1.1.3 Introduction to Electronic Discharge Communication Tools:

Electronic discharge communication tools (eDCTs) are one potential approach to narrowing the communication gap. Broadly speaking, eDCTs consist of at least one of two features: automatic population of discharge documents by computer database and/or transmission of discharge information via the Internet(11). Such communication platforms can provide an immediate link between acute care and primary care physicians. Interfaces can be designed to ensure consistent, comprehensive and timely information transfer, ultimately reducing the risk of post-discharge adverse events.

1.2 Effectiveness of eDCT:

1.2.1 Effectiveness of Electronic Discharge Communication Tools:

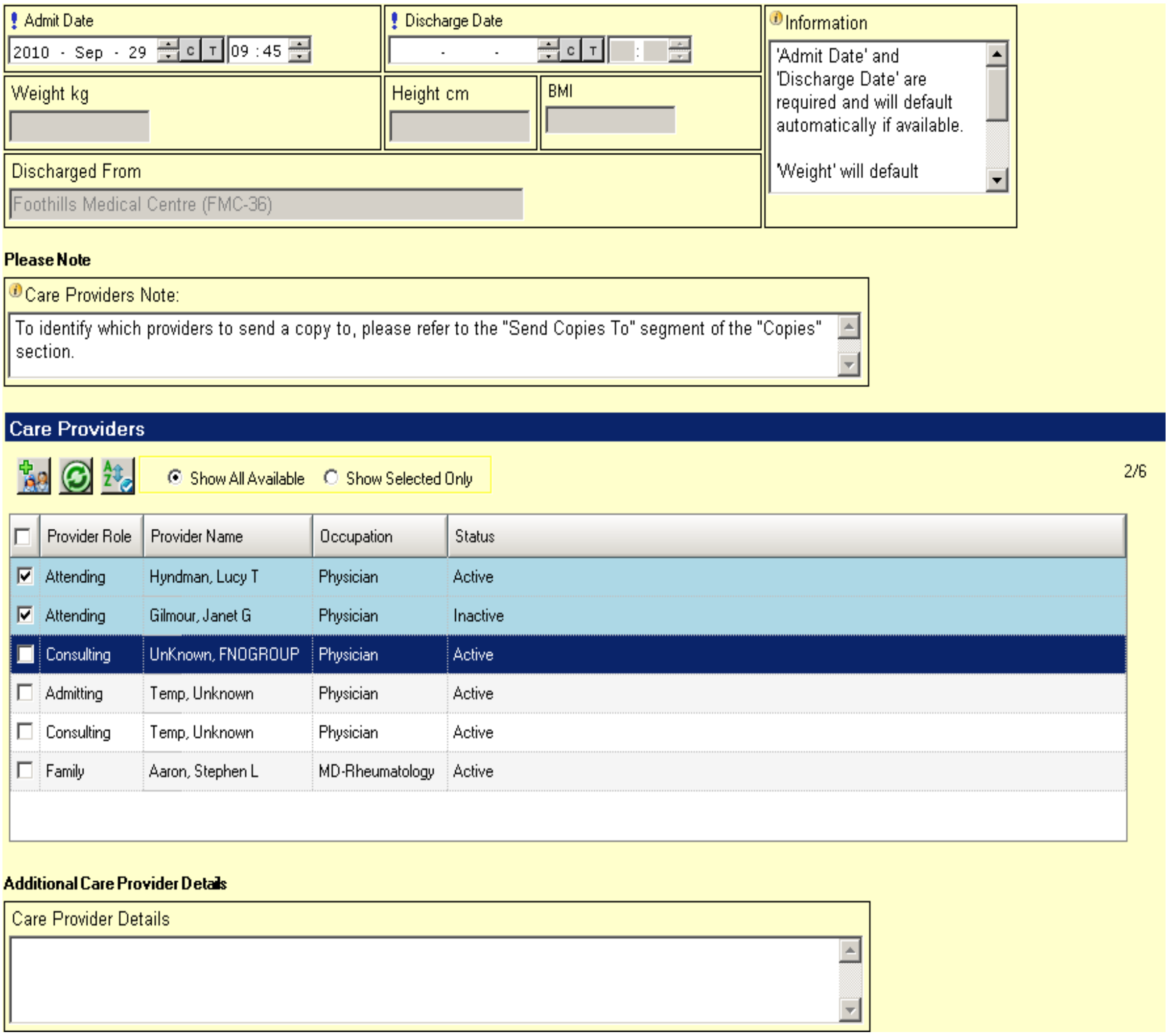
In 2011, Motamedi et al. completed a systematic review on the efficacy of eDCT. The literature search was completed on March 15, 2008 and updated on November 1, 2010(7). Databases searched included MEDLINE, EMBASE, the Cochrane CENTRAL Register of Controlled Trials, the Cochrane Database of Systematic Reviews and MEDLINE In-Process(7). To be considered an eDCT, the study had to use an intervention that had at least one of the following characteristics: (1) automatic-population of the discharge document by computer database; (2) transmission of discharge information via computer technology; or (3) computer technology providing a platform for dynamic bidirectional discharge communication to occur between parties(7).

Twelve published studies were included. The identified studies varied in terms of intervention, study design, study quality and outcomes reported(7). Most studies reported on letter timeliness, completeness/accuracy, and physician or patient satisfaction. For those studies that reported it, mortality and readmission to hospital/emergency departments were similar at 6 months between the intervention and control groups; however, one study did note a significant decrease in readmission rates at 12 months when using an eDCT(7). Limited information on the potential impact of eDCTs on adverse events was found, and none of the studies reported economic evaluation outcomes. All the studies were of moderate quality (using the Jadad scale), and the patient populations, outcomes and interventions used were all heterogeneous(7). Table 1 in the Appendix summarizes the included studies of this systematic review. Overall conclusions from the review were that further scientific studies were needed to understand the extent to which these tools affect patient outcomes(7). Organizations adopting these tools were encouraged to incorporate formal evaluation protocols, and complete economic evaluations.

1.2.2 Development of a novel eDCT:

As per the recommendations made by Motamedi et al. in the systematic review, researchers at the University of Calgary designed a study to assess the efficacy of an eDCT. The eDCT was developed by the Ward of the 21st Century (W21C), a health systems research and innovation initiative, in collaboration with Alberta Health Services (AHS)(12). From the project onset, an iterative consultation process with multiple clinical stakeholders, patients and families was used to develop the tool(12). The tool was built off the Sunrise Clinical Manager electronic platform, which is the current platform used by physicians to manage inpatient orders and access patient medical records, diagnostic imaging and laboratory results(12). Figure 2 provides a screenshot of *Visit Date Section* of the novel eDCT. An additional screenshot of the *Medication Section* can be found in the appendix.

Figure 2: Novel eDCT Screenshot (From Santana et al.)



This eDCT was initially piloted through the Medical Teaching Unit (MTU), a general internal medicine ward affiliated with the W21C. One hundred transfers of care from acute care to primary care were conducted, and a detailed assessment of the usability, completeness and timeliness of the discharge summaries was completed(12). Patient and provider satisfaction were also captured. Adjustments to the tool were made to ensure the needs of acute care physicians, primary care physicians and patients were met(12).

1.2.3 Assessment of Efficacy:

The efficacy of the tool was then analyzed using a Canadian Institute for Health Research (CIHR) funded randomized control trial (RCT). Patients were eligible for study inclusion if they were admitted to the MTU. Patient exclusion criteria were: 1) under 18 years; 2) unable to provide contact information; 3) lacking English proficiency and without a family member or friend through whom the team could communicate; 4) enrolled in 2 or more other studies; 5) unwilling to provide consent; 6) non-Alberta residents (essential for determining follow-up outcomes); 7) previously enrolled in the study; 8) being discharged to hospice; 9) transferred to another hospital; 10) transferred from the MTU to another service in the study hospital; or 11) died in hospital or remained in hospital without prospects for discharge home(13). Included patients were randomized to discharge using either the eDCT (n=701) or usual care (n=698)(13).

Baseline information included socio-demographics, admission diagnosis, Charlson co-morbidity index variables, and health related quality of life using the Health Utilities Index Mark 3 (HUI-3)(13). The primary outcome was a composite of death or readmission to any provincial acute-care hospital within 3 months of discharge. Patients were linked to data from the Alberta Health Services Data Integration, Measurement, & Reporting unit and the Alberta Bureau of Vital Statistics to capture readmissions and all-cause mortality respectively. Secondary outcomes included patient reported adverse outcomes and patient reported adverse events at 30-days post discharge. Secondary outcomes were captured through telephone interviews by a trained investigator.

There was no statistically significant difference between groups for the composite end-point of mortality or death at 90-days (32.8% eDCT compared to 29.4% Usual Care,

p=0.166)(13). However, when the components of the composite are considered individually, readmissions were higher for the eDCT group, while mortality was lower for the eDCT group(13). Secondary outcomes examined were also not statistically significant(13). Future studies should avoid the use of a composite endpoint, and instead be powered to statistically analyze the difference between both mortality and readmissions separately at 90-days(13).

1.2.4 Physician Experience Adopting the Electronic Discharge Communication Tool:

A cohort study of acute care physicians (those producing the discharge summaries) and community care physicians (those utilizing the discharge summaries) was completed to assess physician user experience (14). A validated survey was used to collect data from acute care physicians both at pre-rotation and post-rotation, to show how their experience changed after recent exposure to the tool and after gaining familiarity with the tool. Survey results were collected between March 2013 and December 2014 over ten rotations of residents for acute care physicians, and between June 2013 and January 2014 for community care physicians(14).

Overall, 138 acute care physicians were surveyed. Of those, 68 had previous exposure to the tool and indicated a preference for eDCT at the pre-rotation stage(14). After rotation, acute care physicians indicated that they did not find the tool difficult to use. They also showed a preference for using the eDCT over traditional discharge(14).

For the community care physicians, 72% indicated that they had received the discharge summary at the time of the first follow up visit using the eDCT(14). Community care physicians found the eDCT generated discharge summaries to be useful in terms of patient care; however, there was no difference in quality between electronically generated and traditional dictation discharge summaries(14).

Strengths, barriers and opportunities for the eDCT were identified from the qualitative thematic analysis(14). Acute care physicians highlighted that they liked the ability to start and stop the discharge letter using the eDCT, and that it allows for day-to-day additions(14). This contrasts with traditional discharge, which requires complete dictation at the end of the patient's hospitalization. Time required and formatting of the eDCT were revealed as barriers(14). For community care physicians, access, timeliness, and quality of information and continuity of care were major themes. Some community physicians indicated a preference for fax; however, some indicated an appreciation for the timeliness with which an eDCT discharge summary is available(14). Finally, community physicians described a preference for receiving more information regarding context and continuity of care(14).

1.2.5 Overall Assessment of the eDCT:

While eDCTs are a potential solution for bridging the communication gap between in-hospital and community-based care, the true cost and value of these tools remains unknown. For instance, Alberta's Deputy Health Minister recently acknowledged the importance of electronic communication interventions, and announced plans to create a single electronic health information system to connect acute care physicians with primary care physicians across the province(15). Within this announcement, eDCTs were identified as a required component for the future electronic system(15). Cost estimates for the implementation of this system have been in the hundreds of millions of dollars, while the impact of these systems on clinical care remains largely unknown. Prior to provincial implementation and adoption, these systems should be evaluated to ensure that they are of good value for money.

1.3 Introduction to Economic Evaluations:

Choice, scarcity and opportunity cost are the foundations of health economics(16). Specifically, due to limited resources (scarcity) and the inability to adopt all health technologies that produce the desired output of improved health, choices must be made. Health economics also considers the benefit forgone by committing resources to one choice and not the other (opportunity cost). These foundation concepts led to the development of economic evaluation methodology. An economic evaluation is “the comparative analysis of alternative courses of action in terms of both their costs and consequences”(16). Overall, economic evaluations capture and examine the inputs and outputs of all alternatives being considered. Based on the nature of the desired outcomes (benefits or consequences), different techniques for economic evaluations can be used.

Economic evaluations are also used to inform system efficiency, the relation between scarce resources and health outcomes(17). Maximizing efficiency ensures systems achieve the best value for money from their scare resources. In health economics, there are two types of efficiency to be considered: technical and allocative efficiency. Technical efficiency is maximized when the greatest health improvement is achieved from a set of resource inputs(17). Moreover, technical efficiency should be considered in situations where resources have been allocated to a specific group of patients, and decisions are now concerned with how to maximize health outcomes for this patient population(18). In contrast, allocative efficiency informs broader resource allocation decisions(17). Allocative efficiency requires comparisons of different groups of patients, and how best to allocate scarce resources to maximize health outcomes across the population(18).

1.3.1 Types of Economic Evaluations

As previously mentioned, there are different types of economic evaluations. The type of evaluation used should be based on the desired outcomes and the type of efficiency the evaluation is seeking to inform. Overall, there are three general types of economic evaluations used in health economics.

Cost-effectiveness analysis (CEA) can be used to examine the relationship between costs and a single common effect that may differ in magnitude between choices, or more simply, CEA determines the cost per unit of effect(16). For example, this type of analysis can be used to determine the cost per life year gained, the cost per life saved and/or the cost per hospital readmission avoided(16). CEA can be used to inform decisions of technical efficiency. A decision-maker that is considering a limited range of options with a common health effect can use this analysis. CEA may not be useful to decision-makers with a broad mandate, as health technologies and interventions may vary greatly in their units of effect. Moreover, examining the cost per life saved may not be appropriate for all health interventions.

If the desired outcome is a combination of quantity and quality of health produced (or forgone) by an intervention, a cost-utility analysis (CUA) can be used. Specifically, in this type of analysis, the incremental cost of the intervention is compared with the incremental health improvement caused by the intervention(16). As the name suggests, CUA measures health benefit in terms of utility, and considers individual preferences for particular health states. The overall outcome of this analysis is a cost per Quality Adjusted Life Year (QALY). The benefit of this form of analysis is that it produces a generic outcome that can be used to compare a variety of different health interventions, and can inform decisions concerned with both technical and allocative efficiency(16). In contrast to CEA, this form of analysis is particularly useful for decision-makers with a broad mandate.

Finally, a cost-benefit analysis (CBA) puts both the inputs and outputs (costs and consequences) of all choices into monetary terms. The outcome of this analysis is a ratio of costs to benefits, and the absolute benefit of the choices being considered(16). CBA provides insight into the value of resources used compared to the value of resources saved (or created) by the intervention. Given that both costs and benefits are presented in monetary terms, CBA can be used to inform allocative efficiency; however, CBA is not often used in healthcare decision making, as it is difficult to measure health benefits in monetary terms.

1.3.2 Measuring Utility

As described above, CUA can be used to inform both technical and allocative efficiency. Unlike CBA, CUA does not require health benefits be measured in monetary terms. This makes it an attractive analysis for informing healthcare decision making. CUA measures utility based on individual and societal preferences for particular health states. There are two general ways of measuring utility: direct measurement and indirect measurement(16).

Direct measurement requires mapping of preferences directly onto a utility scale(16). This can be achieved using Standard Gamble, Time Trade Off and Visual Analog Scale methodologies. In these methodologies, respondents directly express their preferences for specific health conditions by trading off between health states(16). While these methods are useful for measuring utilities, they are also costly and time consuming.

Indirect measurement requires mapping preferences onto the utility scale using a generic health related quality of life questionnaire(16). This allows researchers to bypass the time-consuming process required for direct measurement. There are four multi-attribute health status classification systems with preference scores that can be used for this purpose. They are the Quality of Well Being, Health Utilities Index, EuroQol 5 Dimensions, and the Short Form 6 Dimensions. When deciding which of these tools to use researchers should consider if the attributes and levels of attributes used in each of the tools are likely to be important to the population being examined, if the tool has been used in similar patient populations, and if the instrument is likely to be responsive to the expected changes(16).

1.3.3 Using Economic Evaluations in Decision Making

Overall, economic evaluations are a useful tool to healthcare decision makers, as they provide outcomes that allow for the comparison of interventions. The comparison of interventions using economic evaluation methodologies, can help ensure that decision makers are making decisions that are of good value for money. This is particularly important for public healthcare systems, which have limited resources. Furthermore, evidence informed decision-making (including economic evaluations) helps ensure that tax-payer dollars are being spent on the interventions that provide the best health outcomes for the dollar amount spent.

1.4 Study Objectives

Based on the identified knowledge gap and the results of the clinical trial, the study objectives for this thesis are as follows:

<u>Primary Objective</u>: To establish the cost and cost per quality-adjusted life year (QALY) of eDCT compared to traditional discharge systems, using a publicly funded healthcare system perspective, for individuals who have completed care with one provider and are transitioning care to a new provider care.

Secondary Objective 1: To determine the *cost per life saved* using an eDCT compared with traditional dictation using a publicly funded healthcare system perspective, for individuals who have completed care with one provider and are transitioning care to a new provider care.

Secondary Objective 2: To determine the *cost per hospital readmission avoided* using an eDCT compared with traditional dictation using a publicly funded healthcare system perspective, for individuals who have completed care with one provider and are transitioning care to a new provider care.

1.4 Thesis Overview

Given the above stated knowledge gap and study objectives, the remainder of this broken down into three chapters. Chapter Two presents a comprehensive review of all the economic literature surrounding eDCTs. Chapter Three provides a prospective economic evaluation of a novel eDCT. This analysis was completed alongside the previously described RCT. Finally, given the results of Chapter Two and Three, Chapter Four presents a range of policy options that should be considered moving forward.

Chapter Two: A Systematic Review of the Cost and Cost-Effectiveness of Electronic Discharge Communications

Short Title: Cost of Electronic Discharge Communications

Author List: Laura K Sevick, Rosmin Esmail, Karen Tang, Diane L Lorenzetti, Paul Ronksley, Matthew James, Maria Santana, William A Ghali, Fiona Clement

Abstract

Background: The transition between acute care and community care can be a vulnerable period in a patients' treatment due to the potential for post-discharge adverse events. The vulnerability of this period has been attributed to factors related to the miscommunication between hospital and community-based physicians. Electronic discharge communication has been proposed as one solution to bridge this communication gap. Prior to widespread implementation of these tools, the costs and benefits should be considered.

Objective: To establish the cost and cost-effectiveness of electronic discharge communications compared to traditional discharge systems, for individuals who have completed care with one provider and are transitioning care to a new provider.

Methods: We conducted a systematic review of the published literature, using best practices, to identify economic evaluations/cost-analyses of electronic discharge communication tools. Inclusion criteria were: 1) economic analysis, 2) electronic discharge communication tool as the intervention. Quality of each article was assessed, and data were summarized using a component-based analysis.

Results: One thousand unique abstracts were identified and fifty-seven full-text articles were assessed for eligibility. Four studies met final inclusion criteria. These studies varied in their primary objectives, methodology, costs reported and outcomes. All the studies were of low to good quality. Three of the studies reported a cost-effectiveness measure ranging from an incremental daily cost of decreasing the average discharge note completion by one day of $0.331 (2003 Canadian), a cost per page per discharge letter of €9.51, and a dynamic net present value of €31.1 million for a five-year implementation of the intervention. None of the identified studies considered clinically meaningful patient or quality outcomes.

Discussion: Economic analyses of electronic discharge communications are scarcely reported, and with inconsistent methodology and outcomes. Further studies are needed to understand the cost-effectiveness and value for patient care.

2.1 Background:

The transition between acute care and community care can be a vulnerable period during patient care due to the potential for post-discharge adverse events. Recent studies have estimated the incidence of adverse events to range from 19-23% within 2-5 weeks post discharge(1, 2). Of these events, 21% of patients required additional physician visits, 17% required hospital readmission, and 12% presented to the emergency department(1, 2). These events constitute a costly and potentially avoidable resource use.

The vulnerability of this period has been attributed to three main factors all related to the miscommunication between in-hospital and community-based physicians(4), including: 1) failure to reconcile medications, 2) giving the patient or patient's family the responsibility of relaying essential discharge information to the primary care physician, and 3) failure to transfer crucial information between hospital and primary care physicians(4). Electronic communication tools have been proposed as one option to bridge this communication gap by providing an immediate link between acute care and primary care physicians. This contrasts with traditional discharge systems where a discharge summary is prepared by a physician either by hand or using a dictation tool. The summary is then signed by the physician and sent to the family doctor using fax or mail systems.

A 2011 systematic review examined the efficacy of electronic discharge communications, identifying eight randomized control trials and four quasi-experimental studies(7). While the reported outcomes varied across included studies, the overall conclusions from the systematic review recommended implementation of computer-based discharge tools; however, due to the lack of rigorous evidence, organizations were encouraged to incorporate formal evaluation protocols(7).

Along with the efficacy of these tools, the associated financial costs must be considered prior to implementation. This is particularly true for the public sector, which has a limited budget and where implementation will require the reallocation of funds. The cost-effectiveness of these tools remains unknown, and to our knowledge there are no preexisting systematic reviews examining this evidence. By considering the costs and benefits of these electronic tools, in comparison to other uses of resources, decision-makers can optimize the health impact of scarce healthcare resources. The objective of this study was to establish the cost and cost-effectiveness of electronic discharge communications compared to traditional discharge systems, for individuals who have completed care with one provider and are transitioning care to a new provider by reviewing the economic and health economic literature.

2.2 Methods:

A pre-specified review protocol was developed and followed for all methods (LS, RE, KT, DLL, PR, MJ, FC). PRISMA reporting guidelines were utilized(19).

2.2.1 Search Strategy:

MEDLINE, EMBASE (Excerpta Medica Database), EconLit, Pubmed, National Health Services Economic Evaluation Database (NHSEED), and Web of Science were searched from database inception until October 2015. A Master of Library and Information Science librarian developed a detailed search strategy. For all databases terms/keywords were combined from the following three themes: (1) Economic; (2) Discharge; and (3) Electronic/Computerized. Medical Subject Headings (MeSH) terms used included: medical economics, hospital economics, Markov Chains, patient discharge, patient discharge summaries, and electronics. The initial search strategy was developed for use in MEDLINE and then adapted for the other databases. No limitations on year, language, or human populations were used. Hand searching reference lists of studies included was also conducted. Full details are available in the Appendix.

2.2.2 Study Selection:

Titles and abstracts were reviewed independently by two investigators (LS and RE). The reviewers were not blinded to the study journal or authors. This initial screen was broad and citations were excluded if they were not an economic evaluation or cost-analysis, did not use a discharge intervention, or used a non-electronic intervention. Electronic communications were defined as being at least one of the following three statements: Automatic population of a discharge document by computer database(s) (apps included); transmission of discharge information via computer technology; or computer technology providing a 'platform' for dynamic discharge communications(7). Discharge was defined as *completion* of care with one provider and transitioning care to another provider, to differentiate discharge from referrals to medical specialists. No further restrictions on population, comparison, and economic study design were used. Titles/abstracts identified by either reviewer were included in the full text review. Agreement among reviewers was quantified using the Kappa (κ) statistic.

Full text articles were retrieved and reviewed in duplicate by the same two investigators (LS and RE). Articles were excluded if they were published in abstract form only, not an economic evaluation or cost analysis, the intervention was not discharge related, the intervention was not a summary tool, or if the intervention was not electronic. The same definitions of discharge and electronic communications used in the abstract review were also used during the full text review. No further restrictions on population, comparison, and economic study design were used. Agreement (κ statistic) was also calculated at this stage.

2.2.3 Data Extraction and Analysis:

The primary outcomes of interest were cost-effectiveness, cost-utility, cost-benefit, and costs. Specifically, outcomes of interest from the cost-effectiveness studies included cost per readmission avoided and cost per life saved. The outcome of interest from the cost-utility analysis was cost per quality adjusted life year.

Data were extracted in duplicate by two investigators (LS and RE). This included: year, population, outcomes, intervention, comparator, model details (time horizon, discount rate, currency), and results (net present value, incremental cost-effectiveness ratio, costs, etc.). All differences in data extraction were resolved through review of source documents.

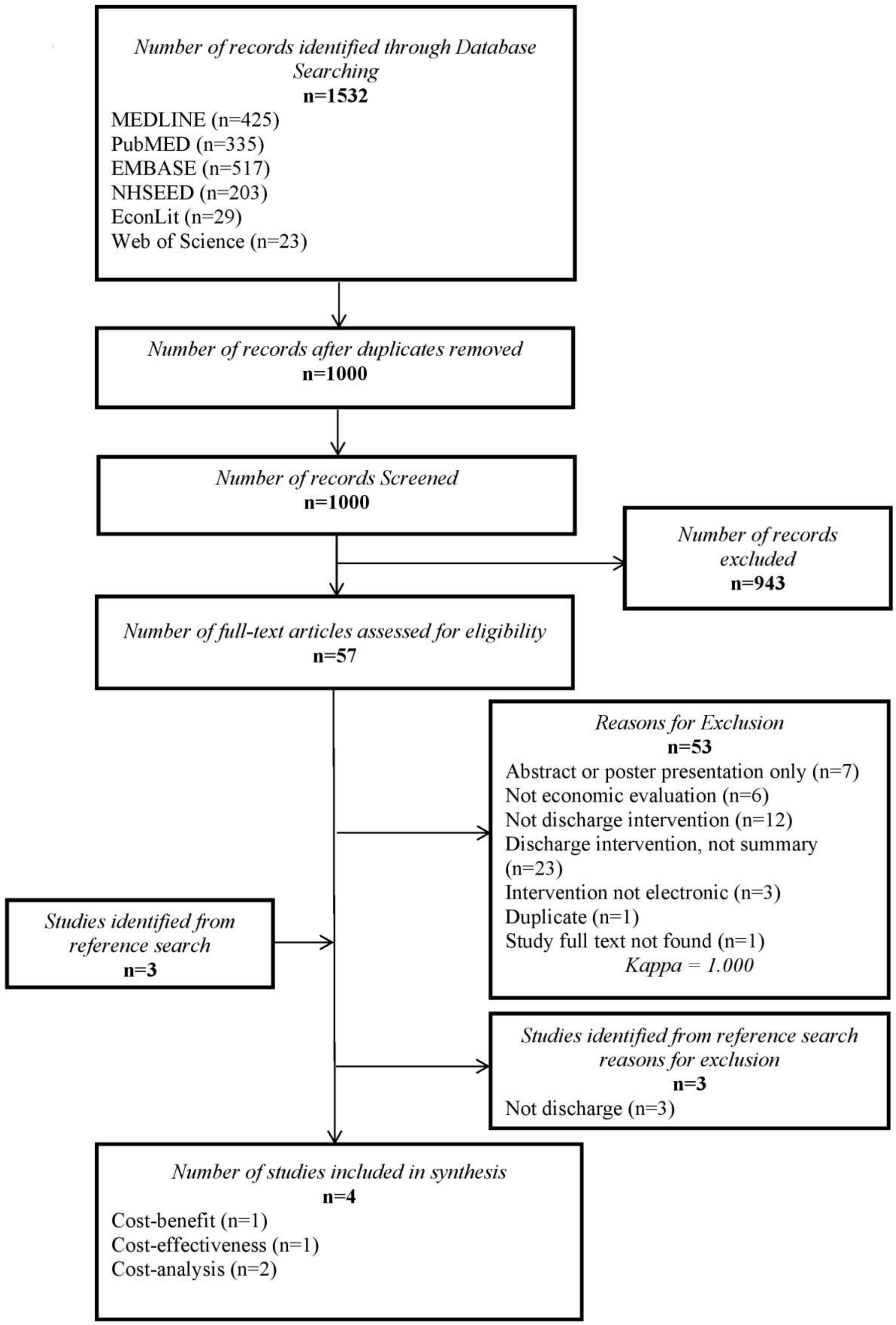
Study quality and risk of bias was assessed using the Consensus Health Economic Criteria (CHEC) list; a checklist that can be used to critically appraise published economic evaluations(20). This 19-point checklist includes reporting standards for economic model characteristics (population, time horizon, perspective, discount rate, etc.), identification and valuation of costs and outcomes, discussion points, conclusions, as well as funding and conflicts of interest. The CHEC list was completed in duplicate (LS and RE) with differences resolved through consensus and review of source documents.

A component-based analysis was used to describe and synthesize the included studies. Specifically, tabulation methods were used to report on study characteristics, outcomes and costs.

2.3 Results:

The literature search identified 1000 unique citations. Of these, 943 abstracts were excluded when both reviewers agreed that they were not relevant to the systematic review, 57 full-text articles were assessed for inclusion. Four unique articles met final inclusion criteria (κ = 1.000). The reference lists of the four identified articles were hand searched. An additional three articles were identified; all were excluded (Figure 3).

Figure 3: PRISMA Flow-chart of Included Studies



2.3.1 Included Studies:

In total, one cost-benefit, one cost-effectiveness and two cost-analysis studies were identified(21-24). All four studies were conducted in different countries with publication dates ranging from 2005 to 2011. Direct translation from German to English was used for one article(22). All four studies focused on the transition from hospital to community care, with one study specifying intervention use in a dermatology department(21-24). One study focused on a dictation tool, which generated signatures electronically and used electronic dissemination(21), two studies generated electronic discharge letters through auto-population by medical records(22, 24), and one used an electronic platform(23). Table 1 provides a summary of study characteristics.

Table 1: Characteristics of Included Studies by Year

Study: authors, country (year)	Country	Methodological Approach	Population	Intervention	Comparator	CHEC* Score
Kopach, R., *et al*, (2005) (21)	Canada	Cost-effectiveness	Automation of medical documentation for entire hospital discharge	Speech recognition technology – signatures generated electronically, final documents sent through email or e-fax	Dictation through telephone used to created voice file to be transcribed – paper based signatures and traditional mailing	18
Colsman, A., *et al*, (2009) (22)	Germany	Cost-analysis	Dermatology department including 4 physicians and 3 typists	Electronic medical record system combining laboratory, experimental findings, nursing performance indicators – separate text editor used for writing discharge letters	Typists used to create discharge document	10
Aanesen, M., *et al*, (2010) (23)	Norway	Cost-benefit	10 hospital departments and 9 primary care physicians	Discharge summary created electronically and sent electronically	Paper based discharge	12
Mourad, M., *et al*, (2011) (24)	USA	Cost-analysis	600 bed quaternary care academic institution	Note Writer with both free-test and auto-populated fields. Separate software tracks signatures and automatically triggers dissemination	Orally dictated discharge notes	7

*Consensus Health Economic Criteria list

2.3.2 Study Quality:

Only one study was of good quality with a score of 18 out of 19(21). The other three studies were of low quality, with scores ranging from 7 to 12 out of 19 (Appendix: Table 2). All clearly described the study population and competing alternatives, while also having a well-defined research question. However, only one of the studies reported standard economic analysis components in a consistent manner(21). None of the studies appropriately discussed ethical and distributional issues as they relate to the study population. Furthermore, possibly due to the nature of their study design, the two cost-analyses did not report a time horizon or a discount rate. In the results section, only one study fully described their study parameters and completed a sensitivity analysis(21).

2.3.3 Primary Objectives and Outcomes:

All the included studies varied in their primary objective (Table 2). Kopach et al. focused on the cost-effectiveness of dictation(21), Colsman et al. focused on time savings due to auto-population(22), Aanesen et al. looked at decreased value of a system due to late adoption(23), and Mourad et al. presented a business case for the implementation of electronic discharge communications(24). All studies also varied greatly in their reported primary outcome. Kopach et al. was the only study to report a cost-effectiveness ratio(21). The other three studies reported costs per discharge page for the intervention and the comparator(22), dynamic net present value (used to determine optimal investment policy(25)) of the intervention(23), and costs associated with the comparator(24). Two studies acknowledged that electronic discharge would be costlier compared to traditional dictation(21, 22), and might not be beneficial to all users(22).

Table 2: Conclusions and Findings of Included Studies by Year

	Primary Objective	Primary Outcome	Conclusions
Kopach, R., *et al* (2005) (21)	Compare the automation of medical discharge notes for in-patients to a current medical documentation system and determine if it is cost-effective.	Incremental cost effectiveness ratio (ICER) of **$0.331** (in 2003 CDN $).	Automated documentation system costs more, but reduces document completion time. Spending an additional $0.331 per discharge, average time of note completion decreased by one day.
Colsman, A., *et al* (2009) (22)	Determine the extent to which a hospital information system for patient data supports the creation of a discharge report.	Total cost per page per discharge letter in the comparator is **€10.71**. Total cost per page per letter in the intervention is **€9.51**.	Creation of discharge letter in an isolated text editor is advantageous for typists, but not for physicians. To be beneficial for clinicians, it is necessary to improve user experience and expand imports of medical data.
Aanesen, M., *et al* (2010) (23)	Examine the consequences of maintaining an old working procedure when a new technology has been implemented.	Dynamic Net Present Value (DNPV) for 5-year implementation of electronic message exchange in hospitals and primary care units **is €31.1 million**. DNPV for 10-year implementation is **€24.6 million**.	Greater DNPV for faster implementation of electronic discharge tools.
Mourad, M., *et al* (2011) (24)	Present the business case for the implementation of an electronic discharge summary.	Yearly cost of discharge using current system is **$496,400** (USD). Cost of a 14-day delay in billing is **$107,000-$215,000** (USD).	Investing in e-discharge has real-time benefits in the impact on patients, system improvements, qualitative benefits and return on investment.

2.3.4 Costs Reported:

A list of relevant costs to consider when adopting electronic discharge communications was determined through variables identified in the literature (Table 3)(21-24). Only the study by Kopach et al. reported on the costs of the intervention and the comparator(21). The other three studies either reported time savings ratios(22, 23), or only considered the potential costs savings by reporting the expenses associated with traditional paper-based discharge(24). None of the studies considered all infrastructure, personnel and system maintenance costs. Specifically, none of the studies reported costs of network connectivity, server capacity, interface with current records systems, physician training, and computer and network maintenance.

Table 3: Summary of Costs Reported for Included Studies

	Kopach, R., *et al* (21)		Colsman, A., *et al* (22)		Aanesen, M., *et al* (23)		Mourad, M., *et al* (24)	
	Intervention	Control	Intervention	Control	Intervention	Control	Intervention	Control
Infrastructure	+	N/A						
Software/Licensing	+	N/A						
Hardware	+	N/A						
Network connectivity								
Server capacity for backup system								
Interface with current electronic medical records								
Personnel								
Physician champion								
Physician training								
Computer programmer								
Transcription	+	+	+	+				+
Deficiency tracking								
Notification	N/A	+						
Postage/Dissemination	+	+						
Maintenance	+	+						
Computer/printer maintenance								
Network maintenance								
Software add-ons and updates								
Time savings	+	+	+	+	+	+		
Time delays					+	+		+

+ = included in paper
N/A = not applicable

2.4 Discussion:

In summary, this review identified four studies(21-24). The component-based analysis indicated that these studies varied with respect to economic analysis methodologies, primary objectives, primary outcomes, and costs reported. Three of the studies were considered to be of low quality using the CHEC list.

To our knowledge, this is the first systematic review conducted to examine the state of the evidence on the costs and cost-effectiveness of electronic discharge communications. The only previously published systematic review on the efficacy of electronic discharge tools identified that there is support for the implementation of computer-based discharge tools(7). The authors of this review stated that it was uncertain if widespread implementation of these tools would be beneficial without the consideration of efficacy, local context, stakeholder input, patient outcomes and cost-effectiveness(7). The findings of our work demonstrate that the cost-effectiveness is not often reported and, when it is reported, many important aspects of costs are excluded. This would lead to duplication of effort, as individual organizations would be required to develop their own business cases with no readily available template or comparator.

Some studies did report attractive economic findings, particularly as they relate to faster implementation and decreases in time delays. However, the primary outcomes reported make it difficult to compare across tools and to justify the expenditure required for these tools in the greater healthcare system context. All the studies also used differing levels of electronic input (dissemination, auto-population, and platform), and are not representative of all electronic discharge systems. Future studies should consider presenting the costs of the intervention in a dis-aggregated format such that different centers will be able to select costs depending on their current systems and required development process.

Three of the four studies focused on some measure of time savings with respect to the cost analysis(21-23). None of the studies measured meaningful health-related patient or quality outcomes including: patient satisfaction, physician satisfaction, readmission rates or mortality associated with the implementation of electronic discharge. Furthermore, the studies did not measure patient safety outcomes such as the avoidance of adverse events, which could potentially decrease with the implementation of these tools. Notably, only one study identified as a cost effectiveness study, which in healthcare typically provides a cost per clinical benefit. Because this study did not measure meaningful clinical outcomes, it is difficult to ascertain the true cost-effectiveness of electronic discharge tools. This is particularly concerning for publicly funded healthcare systems that must make trade-offs to work within a constrained health budget. Moreover, studies that measure clinically meaningful outcomes, such as the cost per adverse event avoided or cost per readmission avoided, could present a stronger case for tool adoption. Outcomes like the cost per decrease in time delay may not be readily understood by decision makers, and may not be comparable across eHealth tools and healthcare sectors. Future cost-effectiveness studies should ultimately include hard clinical endpoints such as mortality and readmissions. Available reporting guidelines should be followed to improve overall quality.

Besides time savings, most of the studies reported on the costs of transcription(21, 22, 24). However, none of the studies reported on critical costs surrounding network connectivity, server capacity, interface with current medical records, physician training, computer programmers, computer and network maintenance, and software updates. These costs are essential infrastructure, personnel and maintenance costs, which must be considered to ensure the success of implementation and continued use of electronic discharge communication tools. Future studies in this area should focus on addressing all relevant costs while using patient safety and quality outcome measures.

Our understanding of the cost-effectiveness of electronic discharge communication tools is limited by the literature available. Importantly, we suspect many of the large healthcare systems who have adopted electronic discharge communication tools have developed business cases, yet due to the proprietary nature, this important information is unlikely to be publicly available.

The timeliness of the interventions also limits the relevance of the published work. The most recent study (Mourad et al) was published in 2011; it is already four years old(24). For the information technology industry, this is a significant period over which technologies can change. In fact, Kopach et al. in 2005 identified that their system would be irrelevant in three years due to ever changing technology(21). This may also be a deterrent for future studies, given that researchers must rapidly complete and publish their appraisals, for an evidence informed adoption decision to be made. Furthermore, researchers may be discouraged knowing that their work may become obsolete in such a short period. Healthcare systems should be encouraged to rapidly publish their business cases to enable other systems to make evidence-informed decisions about their electronic tool adoption.

Another factor that may be impacting the literature available is the large amount of data and infrastructure required for these tools. For instance, tools that are auto populated by external data sources such as pharmaceutical and diagnostic platforms require extensive hardware, interface systems, maintenance and updates. Systems that have already implemented components of this eHealth infrastructure may be too invested to change their adoption decisions based on the results on a health economic study. This makes a case for pilot studies in systems with modest adoption. These systems would be able to assess eHealth tools, while also taking the results into consideration during their full adoption decision.

The outcomes measured in the studies were all different, and studies were of low to moderate quality. This makes it challenging to generalize the results of these studies to other settings or contexts. A component based analysis and tabular format were used in an attempt to synthesize results and findings from the included studies. Lastly, it is possible that studies may have been missed in the search strategy; however, we feel this is unlikely as we followed standardized systematic review protocols and consulted with a librarian.

2.5 Conclusions:

Despite the focus of implementing electronic discharge communication tools in health care systems, there is a limited amount of information on their cost-effectiveness, and the cost-effectiveness of electronic discharge communication tools cannot be drawn from this review. Future work in this area should focus on conducting research to collect the evidence to support the cost-effectiveness of electronic discharge tools. For decision makers and policy makers that are planning on acquiring electronic discharge communication and tools, cost must be a factor in evaluating which electronic discharge tools to adopt. This becomes even more important during challenging fiscal constraints that health care systems continue to face.

Chapter Three: Prospective Economic Evaluation of an Electronic Discharge Communication Tool

Short Title: Cost-effectiveness of an Electronic Discharge Communication Tool

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Abstract

Background: Electronic discharge communication tools (eDCTs) are one approach to decreasing the communication gap between acute care and community care. It is thought that decreasing this communication gap will lead to a reduced vulnerability for patients in the post-hospitalization discharge period. Prior to the implementation of these tools, the costs and benefits should be considered; however, no economic evaluations examining clinically meaningful or patient safety outcomes have been identified.

Objective: The primary objective of this paper was to complete a comprehensive economic evaluation comparing eDCTs to usual care for patients transitioning from in-hospital to primary care.

Methods: This study was completed alongside a randomized control trial of patients being discharged from an acute-care ward to community care. Patients were randomized to discharge via a novel eDCT or usual care. A healthcare public payer perspective was adopted over a 3-month (90 day) time horizon. Costs considered included: cost of the discharge mechanism, cost of the index hospitalization, cost of readmission, cost of ambulatory care access, cost of drug dispenses, and cost of physician claims. Clinical outcomes of interest included 1) all-cause mortality at 90 days, 2) number of readmissions within 90 days, and 3) the change in quality-adjusted life years (QALYs) from baseline to three months. Incremental cost-effectiveness ratios (ICERs) were calculated for all three of the identified clinical outcomes. Sensitivity analyses were also conducted.

Results: The cost per QALY gained was $239,933.72, the cost per death avoided was $44,051.32 and the cost per readmission gained was $17,490.97 in the eDCT arm compared to usual care. ICERs did not vary greatly with the sensitivity analyses. While ICERs were calculated, there were no substantial differences between the costs and benefits of the trial groups. Thus, resulting in equivalent trial arms.

Discussion: Given that there were no substantial differences in the costs and benefits of using electronic discharge compared to usual care, future work in this area should continue to consider clinically meaningful outcomes while also considering the costs of large scale eHealth adoption.

3.1 Background:

The transition from acute-care hospitalization to community-based care is a vulnerable period in healthcare delivery due to potential for post-discharge adverse events, which may result in additional physician visits, emergency department visits, or hospital readmission(1-3). Previous studies have suggested that the vulnerability of this period may be mitigated by interventions that improve the communication between in-hospital and community based physicians, as the miscommunication between these care providers may result in the primary care physician being unsure of how to proceed with patient treatment(4).

One potential tool for bridging this communication gap is electronic discharge communication. Electronic discharge communication tools (eDCTs) usually consist of an automatic population of discharge documents by computer database and/or transmission of discharge information via the Internet(11). Such platforms allow for immediate communication between care providers, and can be designed to ensure consistent, comprehensive and timely information transfer.

While these tools may improve communication, their costs and benefits should be considered prior to implementation. The previous systematic review identified that there is limited evidence on the cost-effectiveness of eDCTs, and that none of the previous economic evaluations reported patient safety or quality of life outcomes.

Due to the potential clinical and economic benefits, a Canadian Institutes for Health Research funded two-arm randomized control trial was conducted to evaluate the effectiveness of eDCTs(13). Part of this trial included a prospective economic evaluation. Thus, the primary objective of this paper was to complete a comprehensive economic evaluation comparing eDCTs to usual care for patients transitioning from in-hospital to primary care.

3.2 Methods:

3.2.1 Overview of approach:

A prospective economic evaluation of eDCT (treatment) compared to usual care (control) was conducted alongside a randomized control trial (RCT). The RCT was a two-arm trial comparing eDCTs to usual care, defined as traditional discharge communication generated by dictation, for patients being discharged from a Canadian tertiary care center’s internal medicine

Medical Teaching Units (MTUs)(13). These units provide in-patient care to adults who have non-surgical medical problems. Between January 2012 and January 2013, 1,953 patients were approached and screened for inclusion, and 1,399 were randomized to discharge mechanism(13). The RCT was powered to detect a 25% relative reduction in the primary clinical outcome, a composite of death or readmission within 90 days(13). The primary economic outcome was the cost per quality adjusted life year with secondary outcomes of the cost per readmission gained, and the cost per life saved. A healthcare public payer perspective was adopted over a three month (90 day) time horizon. This perspective is representative of the Canadian healthcare system and aligns with the Canadian guidelines for the economic evaluation of health technologies(26). A 90-day time horizon was felt to be appropriate as it reflects a timeline where events could relate to discharge communication and is long enough to permit an event to occur(12). This is also a commonly reported time frame in readmission studies(12). A lifetime horizon was deemed inappropriate, as it is very unlikely that the eDCT will impact a patient's clinical course beyond three months. All costs were inflated to 2016 Canadian dollars using the Canadian consumer price index.

3.2.2 Death, Readmission and Health-Related Quality of Life:

Death and readmissions were modelled separately as these outcomes are valued differently and incur different resource utilization. Death within 90-days post discharge was captured during the clinical trial through linkage to data from the Alberta Bureau of Vital Statistics(13). Readmissions within 90-days post discharge were captured through data linkage to the AHS Data Integration, Measurement, & Reporting unit(13). All readmissions within 90-days were included.

Health related quality of life was measured at baseline, 1-month post-discharge, and 3-months post discharge using the Health-Utilities Index Mark 3 (HUI-3). The HUI-3 is a questionnaire and utility instrument designed to capture patient-reported outcomes for a wide variety of subjects(27). Utility scores were calculated from the HUI-3 data using the HUI-3 Multi-Attribute Utility Function on the Dead-Healthy scale at baseline, 1-month and 3-months(28-30). Average utility was then calculated for each treatment arm. To calculate QALYs at 3-months, the difference in utility scores from baseline to 3-months was multiplied by 0.25 (reflective of the time horizon over one year of life).

3.2.3 Cost of Usual Care: traditional dictation

Costs for traditional discharge communication generated by dictation was provided by estimates from the University of Calgary Medical Group Transcription Services(31). This group provides clinic letters and reports to a wide variety of outpatient clinics across the Calgary zone(31). The base case costs are reflective of the assumed AHS practice where in-hospital dictation transcriptions are all outsourced to an external provider. As is the practice for outsource transcript services, the average cost per minute of dictation was considered in the base case excluding technology fees. The average length of a dictation requiring transcription was estimated using expert opinion. The costs of a printer, printer toner, and paper were excluded; expert opinion reported these costs would be negligible in the base case. Finally, dissemination costs including fax machines were also excluded as these resources are commonly used in the physician offices for a variety of purposes not exclusively for dictation discharges.

3.2.4 Costs of Electronic Discharge:

To estimate the per person costs of electronic discharge, the dis-aggregated costs from the eDCT project estimate were considered. The project estimate captured costs of the development, implementation and pilot testing of the previously described eDCT. Reliability of the project estimate was confirmed by reviewing invoices and receipts. A 5% Goods and Services Tax was also included.

The total estimated cost of the eDCT was then amortized over three years, which is reflective of the technology lifecycle(21). Monthly payments were calculated using an assumed 1% annual interest rate (the Overnight Rate from the Bank of Canada over the trial period(32)). The monthly payment amount was then divided by the average number of discharges from the MTUs per day (~9 discharges/day) multiplied by 30 days(33). A breakdown of the amortization and cost per person calculation can be found in the Appendix.

3.2.5 Healthcare Resource Utilization and Cost:

3.2.5.1 Index Hospitalization:

Index Hospitalization costs were estimated using microcosting data available from Finance Services at AHS, for patients discharged in the 2012-2013 fiscal year (n=1283). Overall, microcosting provides a total direct cost (nurses, doctors, drugs, etc.), total indirect cost (overhead, transportation, electrical, etc.), and total cost per patient. Furthermore, microcosting data includes all hospital resource utilization including operating time, needles, gauze, etc. Microcosting data is the gold standard for economic evaluations, as it allows for a more accurate capture of individual cost variability and is considered the most precise costing methodology(11).

For patients discharged in the 2011-2012 fiscal year (microcosting not completed for this year), and for patients where microcosting data was unavailable, index hospitalizations were linked with the Discharge Abstract Database (DAD) Metadata available through the Canadian Institute for Health Information (CIHI). This data captures administrative, clinical and demographic costs on hospital discharges(34). Costs of the index hospitalization were determined using the DAD Resource Intensity Weight (RIW), which represents the expected resource consumption of an average patient within a Case Mix Group (CMG). CMGs group patients by similar healthcare resource utilization and activities. RIWs can then be multiplied by the Alberta estimates for the Cost of a Standard Hospital Stay available through CIHI to calculate a total cost per admission(34).

Patients that were missing from both the microcosting and DAD data, and for whom an index hospitalization cost could not be estimated (n=45), were assumed to be lost to follow-up and were excluded from the analysis.

3.2.5.2 Readmissions:

Both the cost and number of readmissions were estimated from the DAD Metadata. Patients that were readmitted to the same centre within 12 hours of discharge or another centre within 24 hours of discharge were assumed to be hospital transfers, and counted as one readmission (the recommended algorithm for distinguishing transfers from readmissions by AHS)(35). Like the index hospitalization, the cost of a readmission was estimated using DAD RIWs and Alberta estimates for the Cost of a Standard Hospital Stay. Microcosting data was not available for any of the readmissions.

The average length of stay (LOS) and the average cost per readmission were also calculated. The average number of readmissions was calculated for all patients in each trial arm.

3.2.5.3 Ambulatory Care:

Ambulatory Care utilization and costs were determined by linking trial patients to the National Ambulatory Care Reporting System (NACRS) Metadata available through CIHI. This database contains data for all hospital-based and community-based ambulatory care, including day surgery, outpatient and community-based clinics and emergency departments (ED)(36). The cost per ambulatory care visit was estimated using the NACRS RIW, which represents the expected resource consumption of an average patient within a Comprehensive Ambulatory Classification System (CACS) group(36). The CACS is a national grouping methodology specific to ambulatory care patients. Grouping is based on emergency visits, diagnosis, intervention, and several other ambulatory care indicators(36).

To differentiate between types of ambulatory care utilization, ED visits were separated from other Ambulatory Care visits. For patients who visited the ED, the average LOS and the average cost, were calculated. The average number of ED visits and the total cost were also calculated for all patients. For other ambulatory care, an average number of ambulatory care visits, the average cost and the total cost were calculated.

3.2.5.4 Physician Claims:

To estimate physician resource utilization, Physician Claims and billing codes were provided by Alberta Health. For claims with a $0 cost (indicative of salaried physicians), imputed average physician claim code costs were utilized. These costs were imputed from the Schedule of

Medical Benefits (a list of the fee for each code that a physician may claim) for the fiscal year 2012 and 2013. The imputed costs from the 2012 fiscal year were used for physician claims in the 2011 and 2012 fiscal years, whereas the imputed costs from the 2013 fiscal year were used for physician claims in the 2013 and 2014 fiscal years. To build complete costs for each type of encounter, physician claims were linked by Service Date to index hospitalization, readmission, ED visit or ambulatory care visit dates. If a claim did not have a Service Date, it was removed from the analysis since it was unclear if this claim occurred within the study time horizon. If a physician visit did not link to another type of health encounter, the claim was considered as an independent health encounter such as a visit to a primary care provider.

For the index hospitalization, if a patient was missing from the physician claims data, it was assumed that the patient experienced the average number of claims at the average cost per claim for each treatment arm (eDCT: n=31, Usual Care: n=27).

3.2.5.5 Drug Costs:

Drug costs were estimated using data from the Pharmaceutical Information Network (PIN). PIN data is pulled from a patient’s Alberta Netcare Electronic Health Record, and includes information on their previous and active medications(37). The medications included in this analysis are representative of all dispenses per patient that occurred within three months of the patient’s discharge date.

It was assumed that all patients were under the Alberta Blue Cross Coverage for Seniors (>65 years old) plan. This is a premium free plan provided by the Government of Alberta for senior citizens(38). Under this plan, patients have a co-payment of 30% to a maximum of $25 per dispense; the government pays the remaining cost of the dispensation(38). This plan also assumes that the government pays for the 'Least Cost Alternative' for each drug type when available(38).

Patient dispenses were matched to drug costs using the Alberta Drug Benefit List – April 1, 2016 available through Alberta Health. Linkage was completed using Drug Identification Numbers (DINs). If a dispense DIN was not linked with a DIN in the Alberta Drug Benefit List, this dispense was removed from the analysis, as it was assumed that the drug would not be covered by the Government of Alberta.

3.2.6 Calculating the Incremental Cost-Effectiveness Ratios:

Due to the differing numbers of patients included in each treatment arm (n=679 and n=675), an average cost per patient in each was calculated. The average cost per patient includes: the cost per patient for each discharge mechanism (eDCT or Usual Care), the average cost of the index hospitalization, the average cost of readmission, the average cost of ED visits, the average cost of Ambulatory Care visits, the average cost of drugs, and the average cost of physician claims.

The difference in the average cost per patient was then divided by the difference in the average 'effect' in each arm as per the following Incremental Cost-Effectiveness Ratio (ICER) formula(16).

$$ICER = \frac{(Average\ Cost\ per\ Patient_{eDCT} - Average\ Cost\ per\ Patient_{Usual\ Care})}{(Average\ Effect\ per\ Patient_{eDCT} - Average\ Effect\ per\ Patient_{Usual\ Care})}$$

3.2.7 Sensitivity and Scenario Analyses:

To examine the impact of uncertainty on the model results, both a sensitivity and a scenario analysis were conducted. For the scenario analysis, the costs of the eDCT were varied by increasing and decreasing the project estimate by 25% to show how the cost of the eDCT impacts the ICER. A scenario analysis was also used to show how the costs of traditional discharge impact the cost-effectiveness. Specifically, the costs of traditional discharge using internal transcription with both a non-speech recognition system and a speech recognition system. Speech recognition systems, or computer aided medical transcription, format draft documents that allow medical transcriptionists to edit and review rather than transcribe entire dictations. Thus, increasing transcription productivity. Costs considered for both the internal discharge scenarios include: the monthly technology fee, monthly outsourcing costs, and monthly salary and benefits (including overtime).

3.2.8 Uncertainty Bootstrapping Analysis:

To examine the uncertainty surrounding the trial environment and results, a bootstrapping analysis was completed. Moreover, to examine the variability in the total cost per patient and QALYs gained in each of the treatment arms, random samples of 50 patients for each of the trial arms were replicated 1000 times. The total cost per patient (including the cost of eDCT or usual care and all healthcare resource utilization) as well as the average QALYs gained (between baseline and 3-months) were calculated for each sample. The cost and QALY difference between the two trial arms for each sample is plotted in a scatterplot to present the variability.

3.3 Results:

3.3.1 Patient Population:

Between January 2012 and December 2013, 1,953 patients were approached of which 1,399 MTU patients were randomized to discharge via the eDCT (n=701) or traditional dictation methods (n=698). The Consolidated Standards of Reporting Trials (CONSORT) patient flowchart from the RCT is available in the appendix. There are no noticeable characteristic differences between trial arms (Table 4). This suggests that randomization during the RCT was appropriate.

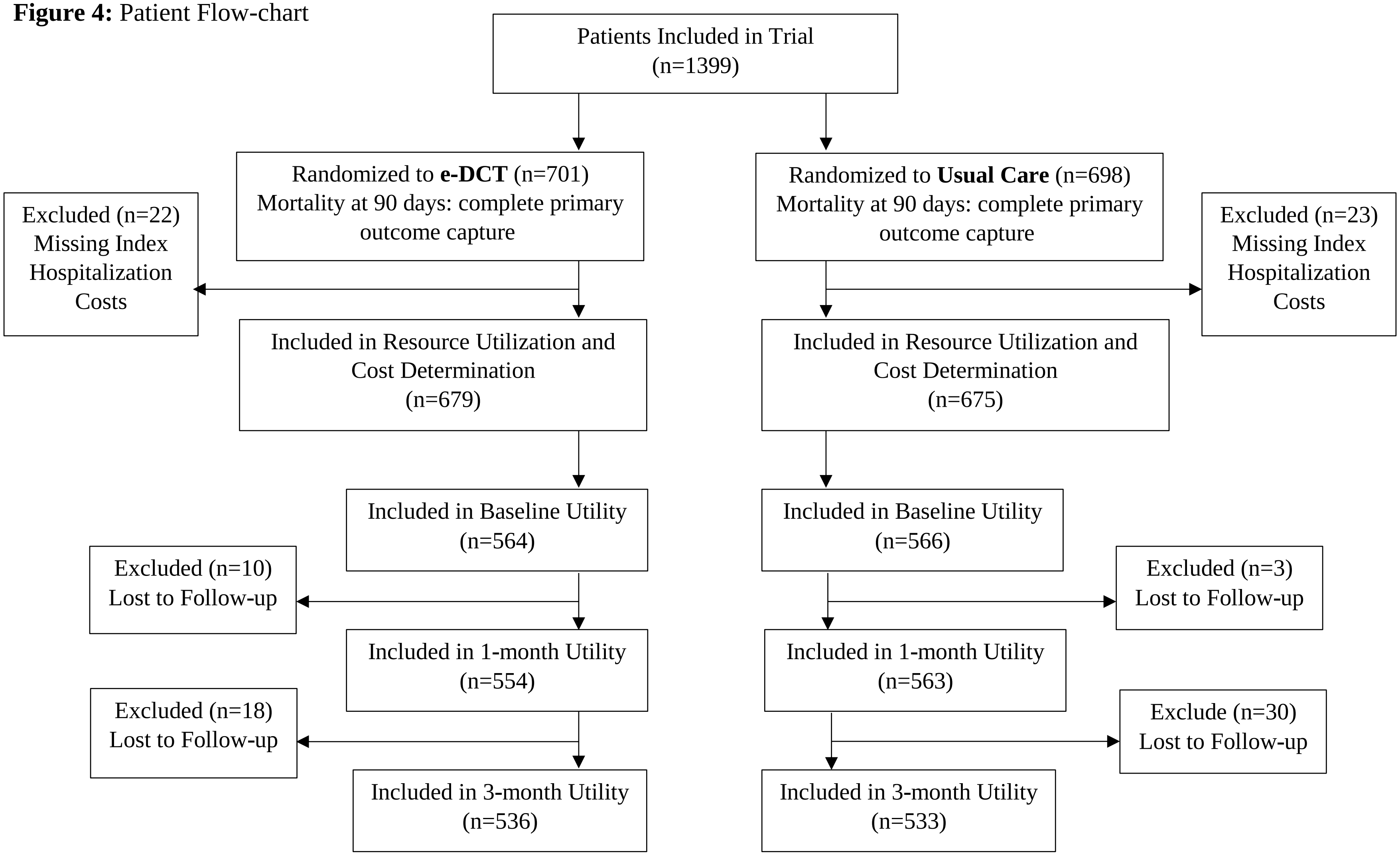
All the randomized patients (n=1399) were included in the 90-day mortality captured during the clinical trial through linkage to data from the Alberta Bureau of Vital Statistics. However, 45 patients were missing index hospitalization costs and were excluded from the cost-analysis (Figure 4). An additional 28 patients in the treatment arm and 33 patients in the control arm were lost to follow between baseline and three months. Utility scores were not available for these patients.

Table 4: Summary of Patient Characteristics by Trial Arm (From Santana et al.)

Characteristics	**e-DCT (n=701)**	**Usual care (n=698)**
Male	377 (46.6%)	373 (53.4%)
Mean Age (SD)	58.8 (17.9)	59.1 (17.9)
Ethnicity		
Caucasian	548 (78.2%)	555 (79.5%)
Asian	38 (5.4%)	38 (5.4%)
East Indian	29 (4.1%)	31 (4.4%)
First Nations	29 (4.1%)	24 (3.4%)
Black	14 (2.0%)	13 (1.9%)
Hispanic	8 (1.1%)	8 (1.2%)
South Asian	8 (1.1%)	2 (0.3%)
West Indian	4 (0.6%)	3 (0.4%)
Other	23 (3.3%)	24 (3.5%)
Current Marital Status		
Married/common-law	380 (54.2%)	388 (55.6%)
Separated/divorced	83 (11.8%)	105 (15.0%)
Widow	85 (12.1%)	76 (10.9%)
Unmarried	153 (21.8%)	129 (18.5%)
Education		
High School or lower	200 (28.5%)	190 (27.2%)
High School	165 (23.5%)	160 (22.9%)
College/University	329 (46.9%)	337 (48.3%)
Undetermined	7 (1.0%)	11 (1.6%)
Current Work Status		
Full/Part-time	211 (30.1%)	198 (28.4%)
Retired	293 (41.8%)	295 (42.3%)
Disability	99 (14.1%)	97 (14.0%)
Unemployed	88 (12.6%)	98 (14.0%)
Student	10 (1.4%)	10 (1.4%)
Patient has a family physician	619 (88.7%)	619 (88.7%)
Patient lives alone	181 (25.8%)	156 (22.4%)
History of Alcohol Abuse	177 (25.3%)	172 (24.6%)
History of Illicit Substance Abuse	67 (9.6%)	65 (9.3%)
Number of Co-Morbidities Median (IQR)	2.0 (0.5-3.5)	2.0 (0.5-3.5)
Diabetes with Organ Damage	158 (22.5%)	166 (23.8%)
Chronic Pulmonary Disease	166 (23.7%)	145 (20.8%)
Liver Disease	118 (16.8%)	126 (18.1%)
Renal Disease	124 (17.7%)	117 (16.8%)
Ulcer Disease	124 (17.7%)	102 (14.6%)
Congestive Heart Failure	95 (13.6%)	101 (14.5%)

Myocardial Infarction	70 (10.0%)	82 (11.8%)
Connective Tissue Disorder	84 (12.0%)	74 (10.6%)
Cerebrovascular Disease	74 (10.6%)	66 (9.5%)
Non-Malignant Solid Tumor	71 (10.1%)	61 (8.7%)
Diabetes without Organ Damage	42 (6.0%)	43 (6.2%)
Peripheral Vascular Disease	50 (7.1%)	37 (5.3%)
Malignant Solid Tumor	30 (4.3%)	30 (4.3%)
Dementia	33 (4.7%)	27 (3.9%)
Malignant Lymphoma	4 (0.6%)	12 (1.7%)
AIDS	8 (1.1%)	7 (1.0%)
Hemiplegia	16 (2.3%)	5 (0.7%)
Leukemia	6 (0.9%)	3 (0.4%)
Mean Charlson Index Score (SD)	7.11 (4.10)	6.98 (4.11)
Main Diagnosis		
Respiratory	60 (8/6%)	28 (4.0%)
Infections	41 (5.9%)	28 (4.0%)
Renal/Kidney	30 (4.3%)	29 (4.2%)
Metabolic/Electrolyte Disorders	24 (3.4%)	30 (4.3%)
Cardiac	27 (3.9%)	29 (4.2%)
Loss of Consciousness	29 (4.1%)	18 (2.6%)
Rheumatology	14 (2.0%)	14 (2.0%)
GI/Hepatic	15 (2.1%)	9 (1.3%)
Poison/Toxic	12 (1.7%)	12 (1.7%)
DVT/PE	5 (0.7%)	7 (1.0%)
Cancer	1 (0.1%)	0
Multiple diagnoses	423 (60.3%)	472 (67.6%)
Diagnoses unavailable	20 (2.9%)	22 (3.2%)
Health Status-Health Utilities Index-overall score HUI3- Mean (Std. Dev.)	0.29 (0.33) N=564	0.31 (0.32) N=566

Figure 4: Patient Flow-chart



3.3.2 Clinical Effectiveness:

Death, readmissions and health-related quality of life were captured and calculated to measure clinical effectiveness (health benefit) of the eDCT (Table 5). Specifically, 5.56% of patients in the treatment arm died within 3 months of discharge compared to 7.45% in the control arm. The average number of readmissions was 0.46 for the eDCT group and 0.41 for the usual care group. Utilities at baseline, 3 months and 6 months were all very similar between the treatment and control groups.

3.3.3 Costs of Usual Care:

For the base case, average cost of discharge per patient in the usual care arm, ten MTU physicians provided estimates for the average length of dictation requiring transcription. The average time was 10.87 minutes (range: 4-22min). Furthermore, the average cost per minute of transcription in the base case was $2.05 resulting in an average cost per patient $22.28 (Table 6).

Table 5: Clinical Effectiveness of e-DCT by Trial Arm

	e-DCT			Usual Care		
	N	Estimate	95% CI	N	Estimate	95% CI
Total mortality at 3-months (%)	701	39 (5.5635)	27.08-50.92	698	52 (7.4499)	38.37-65.63
Average number of readmissions per patient	679	0.4624	0.4063-0.5186	675	0.4148	0.3601-0.4698
Average baseline utility	564	0.2939	0.2670-0.3208	566	0.3090	0.2825-0.3355
Average 1-month utility	545	0.5746	0.5442-0.6051	549	0.5763	0.5464-0.6062
Average 3-month utility	512	0.5725	0.5410-0.6040	500	0.5737	0.5414-0.6061

Table 6: Dis-aggregated Costs of Usual Care ($ 2016 CND)

	Base case	Scenario 1		Scenario 2	
	Outsourced to private firm	Internal Transcription using non-speech recognition system		Internal Transcription using speech recognition system	
Transcription cost ($/min)	2.05	-		-	
Average number of min per dictation	10.87	-		-	
Monthly Technology Fee	-	**$1,421**		**$29,224.00**	
Total Monthly Outsourcing Cost	-	**$28,753.80**		**$28,522.35**	
Monthly Salary and Benefits		Regular	$275,531.00	Regular	$272,929.00
		Overtime	$3,437.00	Overtime	$3,437.00
		Total	**$309,727.00**	Total	**$276,366.00**
Average number of transcriptions completed per month	-	7418		8240	
Average Cost per Patient ($):	**22.28**	**45.75**		**40.55**	

3.3.4 Cost of eDCT:

From the project estimate, the estimated cost of the eDCT was $127,575.00. This estimate broadly captured costs of tool development, tool implementation, training and assistance, maintenance and taxation. After 3-year amortization at a 1% annual interest rate, the monthly payment amount for the tool was $3598.65. This resulted in an average cost per patient to $13.33 (Table 7).

Table 7: Dis-aggregated Costs of e-DCT from Project Estimate ($ 2016 CND)

		Estimated Cost ($)
Development	Project charter & Scope	3,000.00
	Focus Groups (including 12 sessions and reports)	18,000.00
	Data & Security Model	6,250.00
	Initial Prototype (including interface workflow, user management, and systems interface)	31,250.00
	Joint Application (including working session and development)	15,000.00
	Beta Testing	10,000.00
	Application Fine Tuning	6,250.00
Implementation	Transfer to Test Environment (including application install, interface configuration, workflows and configuration)	6,250.00
	Performance Testing & Modifications (including interface, workflow, load testing, and security)	12,500.00
Training and Help	Training	3,000.00
	Documentation & Online Help (including administration manuals, end user guide, and patient guide)	5,000.00
Maintenance	Ongoing Modifications & Support	5,000.00
Tax	Goods and Services Tax (5%)	6,075.00
Total Cost		**127,575.00**
Average Cost per Patient		**13.33**

3.3.5 Healthcare Resource Utilization:

As previously mentioned, costs and resource utilization for the index hospitalization, readmissions, emergency department visits, ambulatory care visits, drug dispenses and physician claims were captured. Table 8 provides a summary of the healthcare resource utilization by trial arm. Overall, there were no noticeable differences between treatment arms.

For the index hospitalization, the average cost per patient was higher in the usual care arm ($17,506.71 compared to $16,832.36). Following the results of the RCT, the average number of readmissions was higher in the in the eDCT arm compared to usual care (0.46 versus 0.41). The average cost per patient was also higher in the eDCT arm ($11,756.11 compared to $10,837.58). Both trial arms experienced the same average number of ED visits (0.78); however, the average cost per patient was higher in the eDCT group $757.83 compared to $683.01). For other ambulatory care access, the eDCT had fewer average number of visits (5.23 compared to 5.69), but at a higher average cost per person ($2,069.97 compared to $1,805.96). The average cost per person for drug dispenses was $245.08 more in the eDCT arm. Finally, the eDCT also had a smaller average number of physician claims (8.04 compared to 8.68), but had a higher average cost per person compared to usual care ($443.97 versus $430.54).

Table 8: Healthcare Resource Utilization by Trial Arm ($ 2016 CND)

		eDCT (n=679)		Usual Care (n=675)	
		Estimate	SD (IQR)	Estimate	SD (IQR)
Index Hospitalization	Average LOS (days)	9.30	10.04 (4-11)	9.19	10.33 (4-11)
	Average hospitalization cost	14,541.83	19,525.33 (4,835.43-15,939.63)	15,117.09	23,023.22 (4,757.48-16,477.81)
	Average number of physician claims*	22.66	22.70 (10-26)	23.28	28.42 (9-25)
	Average cost per physician claim	100.87	65.19 (64.67-108.33)	102.50	67.29 (64.67-116.39)
	Average cost per person	**16,832.36**	**21,756.38 (5,988.60-18,394.78)**	**17,506.71**	**25,955.84 (5,875.89-18,766.40)**
Readmissions	Total number of readmissions (zero count)	314 (446)	19.32§	279 (469)	18.71§
	Average number of readmissions	0.46	0.74 (0-1)	0.41	0.72 (0-1)
	Average LOS (days)	17.24	37.41 (4-15)	18.79	28.63 (4-21)
	Average hospitalization cost	23,613.14	45,418.01 (5,672.44-19,602.89)	24,211.86	37,895.01 (6,190.69-26,160.70)
	Average number of physician claims	26.94	34.26 (7-31)	31.02	40.03 (6-39)
	Average cost per physician claim	105.40	143.27 (64.67-87.33)	104.39	157.78 (64.67-87.33)
	Average cost per person	**11,756.11**	**35,906.67 (0-9,868.78)**	**10,837.58**	**31,155.91 (0-6,385.95)**
Emergency Department	Total number of ED visits (zero count)	530 (393)	37.37§	524 (406)	38.46§
	Average number of ED visits	0.78	1.43 (0-1)	0.78	1.48 (0-1)
	Average LOS (hours)	8.82	5.89 (4.58-11.30)	8.37	6.49 (3.55-11.83)
	Average cost per ED visit	736.69	396.67 (433.37-927.95)	667.34	369.08 (377.61-880.53)
	Average number of physician claims	5.29	4.93 (2-7)	5.36	4.63 (2-7)
	Average cost per physician claim	106.18	81.24 (64.20-160.67)	99.32	77.11 (64.20-120.14)
	Average cost per person	**757.83**	**1,321.17 (0-1,162.63)**	**683.01**	**1,258.36 (0-1,088.96)**

Ambulatory Care	Total number of AC visits (zero count)	3554 (185)	224.66§	3844 (168)	238.61§
	Average number of AC visits	5.23	8.62 (0-6)	5.69	9.18 (1-7)
	Average cost per AC visit	331.42	682.18 (89.12-355.65)	261.52	344.42 (86.83-307.41)
	Average number of physician claims	4.97	5.22 (1-7)	5.15	6.81 (1-6)
	Average cost per physician claim	105.88	97.68 (57.05-142.72)	95.46	89.75 (46.66-116.06)
	Average cost per person	**2,069.97**	**4,212.39 (0-2,297.02)**	**1,805.96**	**3,319.72 (79.66-2,120.66)**
Drug	Average number of dispenses	19.21	22.70 (5-25)	17.54	22.15 (5-23)
	Average cost per dispense	51.34	767.17 (2.07-17.15)	42.63	305.14 (2.19-16.99)
	Average cost per person	**1,018.44**	**4,243.62 (71.20-695.89)**	**773.36**	**2,225.44 (68.73-642.50)**
Other	Total number of physician claims (zero count)	4935 (65)	196.45§	5198 (76)	406.42§
	Average number of physician claims	8.04	7.53 (3-10)	8.68	16.35 (3-11)
	Average cost per physician claim	61.08	54.55 (28.94-72.95)	55.91	56.42 (23.25-64.20)
	Average cost per person	**443.97**	**499.71 (102.75-609.07)**	**430.54**	**458.73 (104.27-588.28)**

*Includes imputed cost for patients missing physician claims data (n=58)

§Standard Error

3.3.6 Total Cost of Trial Arm and Average Cost per Patient:

The total treatment arm costs were calculated as a summation of the total cost per patient for all the following costs: index hospitalization, readmissions, emergency department visits, other ambulatory care visits, drug dispenses, physician claims, and preparation of a discharge summary via electronic discharge or usual care. The total cost for the eDCT arm was $22,448,932.44 and the total cost for the usual care arm was $21,712,759.36 (Table 9).

Table 9: Dis-aggregated Total Costs by Trial Arm ($ 2016 CND)

	eDCT (n=679)		**Usual Care (n=675)**	
	Estimate	Standard Error	Estimate	Standard Error
Index Hospitalization	9,873,901.20	508,783.88	10,204,036.00	598,160.71
Physician Claims - Index Hosp*	1,555,268.60	63,504.25	1,612,991.90	83,133.41
Readmission	7,414,524.80	891,102.88	6,755,110.10	751,009.16
Physician Claims - Readmission	567,875.11	62,043.51	560,258.52	77,788.57
ED Visits	390,447.69	25,314.08	349,686.90	24,606.45
Physician Claims - ER	124,119.30	11,720.11	111,343.00	9,914.69
Other Ambulatory Care	1,177,868.50	101,274.71	1,005,285.20	75,572.78
Physician Claims - AC	227,641.46	14,274.97	213,736.82	14,781.60
Drug	691,523.00	110,578.72	522,020.78	57,818.51
Physician Claims - Other	301,453.52	13,021.35	290,615.17	11,918.17
e-DCT	9,051.07	-	-	-
Usual Care	-	-	15,039.00	-
Total Cost	**22,333,674.25 (1,1861632.50)**		**21,640,123.39 (1,155,396.20)**	
Average Cost per Patient	**32,892.01 (45,538.78)**		**32,059.44 (44,471.22)**	

*Includes imputed costs for missing patients (n=58)

3.3.7 Incremental Cost-Effectiveness Ratio:

In the base case, the cost per QALY gained was $239,933.72 in the eDCT arm compared to usual care (Table 10). The cost per death avoided was 44,051.32 and the cost per readmission gained was $17,490.97 in the eDCT arm compared to usual care.

3.3.8 Sensitivity and Scenario Analysis:

In the first scenario analysis (internal transcription using non-speech recognition system) it was assumed that 7,418 discharge summaries could be transcribed per month with an average cost per patient of $45.75 (calculation in appendix). The ICERs did not differ greatly from the base case results. Specifically, the cost per death avoided was $42,809.52, the cost per readmission gained was $16,997.90, and the cost per QALY gained was $233,170.03. In the second scenario analysis (internal transcription using speech recognition system), it was assumed that 8,240 discharge summaries could be transcribed per month with an average cost per patient of $40.55. This scenario also did not have a large impact on the estimated ICERs. The cost per death avoided was $43,084.66, the cost per readmission gained was $17,107.14, and the cost per QALY gained was $234,668.59.

Decreasing and increasing the cost of eDCT by 25% respectively also had minimal impacts on the calculated ICERs. When increasing the cost of the eDCT by 25%, the cost per death avoided was $44,227.51, the cost per readmission gained was $17,560.92, and the cost per QALY gained was $240,893.37. In contrast to a cost per death avoided of $43,875.13, a cost per readmission gained of $17,421.01, and a cost per QALY gained of $238,974.06 when decreasing the cost of the tool by 25%.

Throughout all the scenario analyses, the cost per death avoided remained above $40,000.00 and the cost per QALY remained over $240,000.00. When considering the cost per readmission avoided, usual care remained the dominant treatment strategy across all analyses (less costly and more effective).

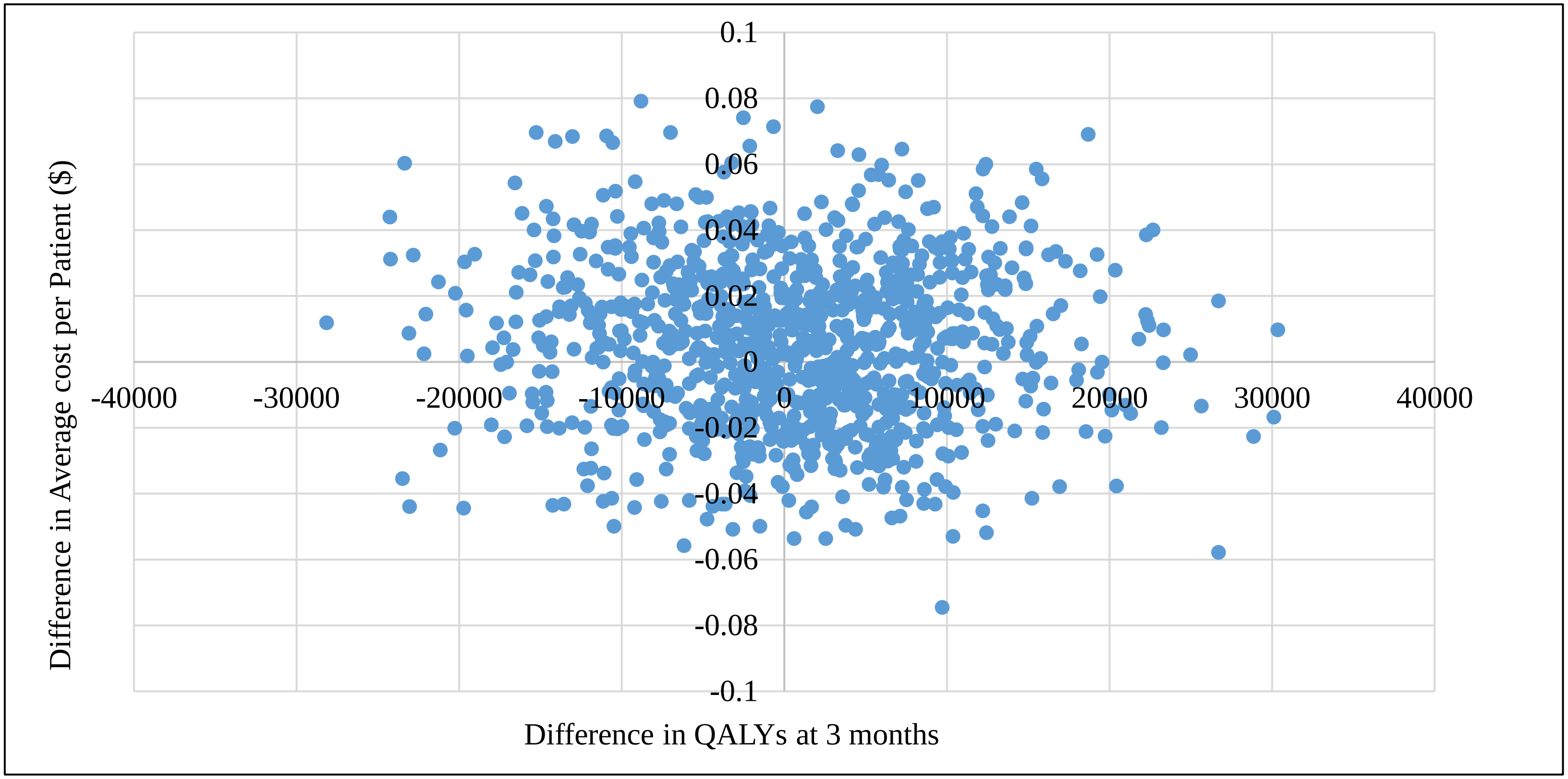
3.3.9 Uncertainty Bootstrapping Analysis:

From the bootstrapping analysis, there is uncertainty in results with similar percentages of the samples falling into each of the cost-effective quadrants (Figure 5). 29.2% of the samples resulted in eDCT being both more effective and more costly, 29.2% of the samples resulted in eDCT being less costly and more effective, 23.9% of the samples resulted in eDCT being less effective and more costly, and finally 17.7% of the samples resulted in eDCT being less costly and less effective.

Table 10: Incremental Cost-Effectiveness Ratios

Base Case							
Treatment	Average cost per patient ($)	QALY	Cost per QALY gained ($/QALY)	Average probability of being alive	Cost per death avoided ($/life saved)	Average probability of readmission	Cost per readmission gained ($/readmission)
Usual Care	32,059.44	0.06618		0.9255		0.4148	
eDCT	32,892.01	0.06965	239,933.72	0.9444	44,051.32	0.4624	17,490.97

Figure 5: Probabilistic Sensitivity Analysis



3.4 Discussion:

Overall, the cost per QALY gained with eDCT compared to usual care is $257,841.50. The cost per death avoided is $47,339.15 and the cost per readmission gained is $18,796.43. The large ICERs are due to the approximate $800 difference in treatment arm costs with minimal changes in health benefit. Results did not drastically change in the scenario analyses.

This economic evaluation examined the cost per readmission gained and the cost per death avoided as separate economic outcomes. From an economic perspective, death and readmissions must be considered separately as they are valued differently by society. In addition, the resource utilization associated with death and readmission is different. However, the RCT was only powered to detect a difference in the composite endpoint of readmissions and death. Due to this, a statistically significant difference in in each outcome was not possible within the trial, and consequently, the economic evaluation.

When considering the cost per readmission avoided (rather than gained), usual care remained the dominant treatment strategy across the base case and scenario analyses. Both the readmissions avoided and the high cost per QALY support the decision to remain with usual care and not adopt an electronic discharge strategy. However, the cost per death avoided remained below $50,000. While there is no commonly adopted threshold for the cost per death avoided (or cost per life saved), since it is difficult to attach a value to an individual's life, some may argue that it should be greater than $50,000. Indeed, one study suggested that interventions with a cost per life saved of less than $61,500 should be implemented(39). With this in mind, the cost per death avoided may suggest that the eDCT is reasonable value for money.

One hypothesis at project onset, was that the eDCT may reduce the number of follow-up primary care physician visits, as the discharge letter would be disseminated in a timely manner. More specifically, the eDCT could help avoid the scenario whereby a patient arrives for follow-up care, the physician has not yet received the discharge summary, and instead re-books the patient for an additional follow-up appointment. Breaking down the physician billing codes did not support this hypothesis. The average number of "other" physician claims, which included primary care physician claims, was only marginally different between the eDCT and usual care arms.

It is important to note that while some of the results do not support the adoption of the novel eDCT, none of the costs or clinical benefits varied between treatment arms. Because of this, both the RCT and the corresponding economic evaluation results can be considered equivalent between the two interventions. Moreover, this evaluation did not produce significant results for or against the adoption of an eDCT. Based on these results, it may be reasonable to consider the costs of the intervention compared to usual care, in isolation from the broader system costs, and expand the consideration of benefits to include other non-clinical benefits and factors that may not have been captured in the RCT.

From the results section, the cost per person cost of eDCT was less than the cost per person of usual care ($13.33 compared to $22.28), suggesting that eDCT is cost savings given the equivalent clinical effect. However, this cost only considered the costs of the pilot project estimate. It is expected that costs of large scale implementation would be much greater than the costs reported in this analysis. Other costs to consider include: the acquisition of the eDCT by the healthcare system, the introduction of the eDCT into existing infrastructure (including current electronic medical records), ensuring appropriate infrastructure and systems for community care physicians, and ongoing software and network maintenance. One expert estimated that the true cost of a provincial eDCT may be closer to $1 million. When considering this large scale provincial lens, it is expected that the cost of eDCT would increase the initial upfront costs.

While large scale adoption may increase the upfront costs of implementing eDCT, it is important to consider how these costs would change given the lifetime and number of patients discharged via the tool. In this analysis, the eDCT was amortized over 3 years, as this is the expected lifetime of the technology reported in literature(21). In practice, this tool has been used at the Foothills Medical Centre since 2012, surpassing its expected lifetime. If the tool had been amortized over more years, the cost per patient would decrease. As eDCT expands to more patients due to large scale adoption, the cost per patient also decreases. Given these factors, large scale adoption may be cheaper than expected. Particularly since the costs of usual care remain constant over time.

To our knowledge, this was the first prospective economic evaluation of an eDCT to be conducted. It provides important insight into the cost and cost-effectiveness of electronic discharge which is rarely reported. Four previous economic studies were identified; however, all the studies varied in terms of quality, primary objectives and primary outcomes, and none of the studies reported on clinically meaningful outcomes(21-24). A previous study determined that while electronic discharge may cost more, it also reduces document completion time(21). However, this prospective economic evaluation did not measure the possible time savings that may accompany electronic discharge. Investigators of the RCT designed the trial to capture clinical benefits from a decrease in time delay (decrease in readmissions and mortality), but did not measure the direct time from discharge summary completion to receipt by a community care physician(12). While the time difference did not manifest in clinical outcomes, the time delay decrease may have other benefits including: acute care physician satisfaction, community care physician satisfaction, and patient satisfaction. This increase in satisfaction may result from not having to complete redundant tasks, not having to repeat oneself, and not having to hunt down additional information to ensure quality care.

Along similar lines, the cohort study of acute and community care physicians completed alongside the RCT, determined that acute care physicians showed a preference for eDCT over traditional dictation and discharge methods(14). Acknowledging this user preference may further increase provider satisfaction. This is particularly important when also considering physician burnout. Moreover, physician burnout, which is usually distinguishable through physician exhaustion, depersonalization, and lack of efficiency, may also lead to decreased patient satisfaction, decreased care quality, and an increase in medical error rates(40-42). Thus, improving provider satisfaction may also lead to improved patient safety and quality outcomes.

It is also essential to consider patient satisfaction in the adoption of eHealth tools. Personal communication with RCT investigators revealed that patients in the eDCT arm often experienced increased satisfaction due to improved information exchange(43). More specifically, patients in the eDCT arm were easily provided with a printout of their discharge summary as they were leaving the hospital. This allowed for more informed patients, and for patients to act as partners in their health care. A recent discussion paper from the Health Information Executive Committee identified that having access one’s heath information better enabled patients to take an active role in the coordination and management of their care(44). Through this mechanism, patients are also able to share information with other care team members(44).

Along with considering patient satisfaction, it is also important to ensure that patient expectations are being met. The same discussion report above also recognized the importance of continuity of care, particularly after citizen concerns surrounding the transitions between points of care began to grow(44). Continuity of care was subdivided into relationship continuity (the relationship between a patient and a single care provider over time), management continuity (sharing information across disciplines, institutions, and providers), and information continuity (the ability to use information from previous events to appropriately address current issues)(44). Patients have the expectation that there is strong continuity of care in their healthcare system. eDCTs are one potential mechanism to improve continuity of care by directly bettering management and information continuity.

An additional benefit of eDCTs not directly addressed in the economic evaluation is the potential research impact. First, because eDCTs can be designed to ensure consistent and comprehensive information transfer, data may be captured through electronic discharge that may have otherwise been missed or not reported. This could allow for more accurate and complete data analysis particularly for the biostatistics and epidemiology disciplines. Second, by automatically imputing data on an electronic platform, researcher time and burden may be reduced, as investigators will not be forced to review paper-based source documents.

This study also had several limitations worth noting. First, this study assumed that all patients were under the provincial Alberta Blue Cross Drug Coverage for Seniors plan. This plan is only available to Alberta citizens over the age of 65. From the RCT, the average age of trial participants was 58.8 in the eDCT arm, and 59.1 in the usual care arm. This suggests that this study may have overestimated the drug costs covered by the Government of Alberta. This overestimation of drug costs may also be leading to an inflation of the ICERs. In addition, a small number of patients were lost to follow-up resulting in some missing data; however, patients were removed from the analysis, and costs were imputed where needed. The RCT experienced physician crossover between trial arms. More specifically, due to the unit of randomization being the patient, a physician may have used the eDCT to discharge one patient, and then immediately switched to usual care to discharge the following patient. This concurrent exposure to the eDCT, which helped ensure consistency of reporting, may have also improved the quality of the discharge summary in the usual care arm. Given this result, the true benefit of eDCT may have been underestimated.

3.5 Conclusions:

This prospective economic evaluation of a novel eDCT showed that there were no substantial differences in the costs and benefits of using electronic discharge compared to usual care. Future work in this area should continue to consider clinically meaningful outcomes while also considering the costs of large scale eHealth adoption.

Chapter Four: Final Discussion and Conclusions

4.1 Discussion

This thesis contained both the first systematic review and the first prospective economic evaluation to examine the cost and cost effectiveness of electronic discharge. From the systematic review, four previous economic studies were identified; however, all the studies varied in terms of quality, primary objectives and primary outcomes, and none of the studies reported on clinically meaningful outcomes. The cost effectiveness of eDCTs could not be established from this review. From the prospective economic evaluation, there were no substantial differences between the costs and clinical benefits of electronic discharge and usual care. This suggests that while ICERs were calculated, the true value of the novel eDCT was equivalent to usual care.

The limited literature identified in Chapter Two and the equivalent results found in Chapter Three highlight a large knowledge gap surrounding eDCTs and eHealth more broadly. Many health systems are moving towards electronic communication and electronic health tools given the current age of technological advancement; however, the true value of these tools remains largely unknown. Some systems are choosing to adopt such tools, as it is also highly speculated and assumed that these tools are often cost saving, given that they reduce the necessity for transcription services, paper, fax machines, etc., yet this result was not identified in either the systematic review or the de novo economic evaluation. Other systems are choosing to adopt such tools due to patient expectations, and a feeling of necessity to remain with the times. Given this knowledge gap and the results of the economic evaluation, there are several policy options that may be considered moving forward.

First, a system may choose to remain with the status quo (usual care). Under this option, a system chooses to continue with the traditional model of physician dictation requiring transcription, and dissemination through paper based mail and fax systems indefinitely. This system requires no additional upfront costs, and is assumed to be as clinically beneficial as electronic discharge. However, this option does not meet patient expectations. This option may also be unreasonable, as many fax-based systems are becoming obsolete.

A second option would be to continue to study individual tools through pilot studies and small scale adoption. This option allows for the modification of original tools, which, when proven effective, can be incorporated into existing systems. This option also meets the public expectation of moving towards a comprehensive electronic system. Considerations regarding this option are the time and monetary investments that would be required. As identified in Chapter Two, the lifespan of most eHealth tools is estimated to be 3 years due to the rapidly changing innovation and technology environment. By the time a study is complete, the eHealth tool might already be considered out of date. Also, the research component would require significant financial investment to remain sustainable. Because this option allows for tools to be incorporated into existing systems, the cost of rolling out these tools would not be insurmountable. Moreover, this option would not require a complete overhaul of all existing eHealth infrastructure, but rather the slow incorporation of unique and novel tools into existing systems.

A third option would be to immediately adopt and incorporate them into current infrastructure. This means that the effectiveness of these tools would not be understood, and that systems may be adopting ineffective tools. Further, this could lead to the inappropriate spending of limited public health dollars. This option would also require significant monetary investment as new eHealth tools and advancements continue to roll out at a rapid pace. Due to monetary constraints and the rapidly changing technology climate, the constant rejuvenation that would be required with this option may be both difficult and unrealistic.

A final, and drastic, option would be to remain with all the current systems, save the money otherwise invested in these tools, and wait for the next huge technological advancement, essentially leapfrogging the current technology into the next wave of technology. Unlike the first option, this option establishes a clear direction and investment moving forwards. With this strategy, a health system may be able to purchase an entirely new communication and technology system that would be regarded as top of the line. This option does not require decision makers to constantly adopt and dissolve, nor would they be required to continually overhaul existing systems in an effort for them to remain current. However, it is impossible to tell the timeline with which this next tech boom might occur, as well as the price tag that might accompany such a project.

Moving forward, decision makers should consider these policy options, as well as their own monetary, time and infrastructure constraints. Other considerations include provider and patient expectations. Systems choosing to continue researching these tools should incorporate the recommendations of the RCT and the prospective economic evaluation in their future analyses.

4.2 Conclusions

Given the results of the systematic review, prospective economic analysis and policy considerations, healthcare systems should think very critically about their current infrastructure and required investment prior to the adoption of eDCTs. For systems operating under a fixed budget, investing in eDCTs will come at the cost of investing in not investing in other technologies and care options. Given that the results of this work find a high cost per QALY due to the small changes in clinical outcomes, the opportunity costs associated with eDCT must be carefully considered.

For systems that have highly developed eHealth platforms, adoption of an eDCT may be more economically attractive. The development of an additional page/tool and its incorporation into a well-managed and comprehensive system would be expected to be low cost, highly feasible and integrated into care delivery. Under these conditions, costs of electronic discharge may be expected to be lower than usual care.

In contrast, systems with non-existent or minimally developed eHealth platforms will require major investment to implement an eDCT. For these systems, remaining with usual care or saving for the next technological advancement may be prudent. In this scenario, eDCT is expected to be more expensive than usual care and without significant clinical benefit. It is also in this situation where adoption of an eDCT would require major trade-offs with other clinically beneficial health technologies.

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Appendix:

A.1 Chapter 1

Figure 6: Screenshot of Novel eDCT Medication Section (From Santana et al.)

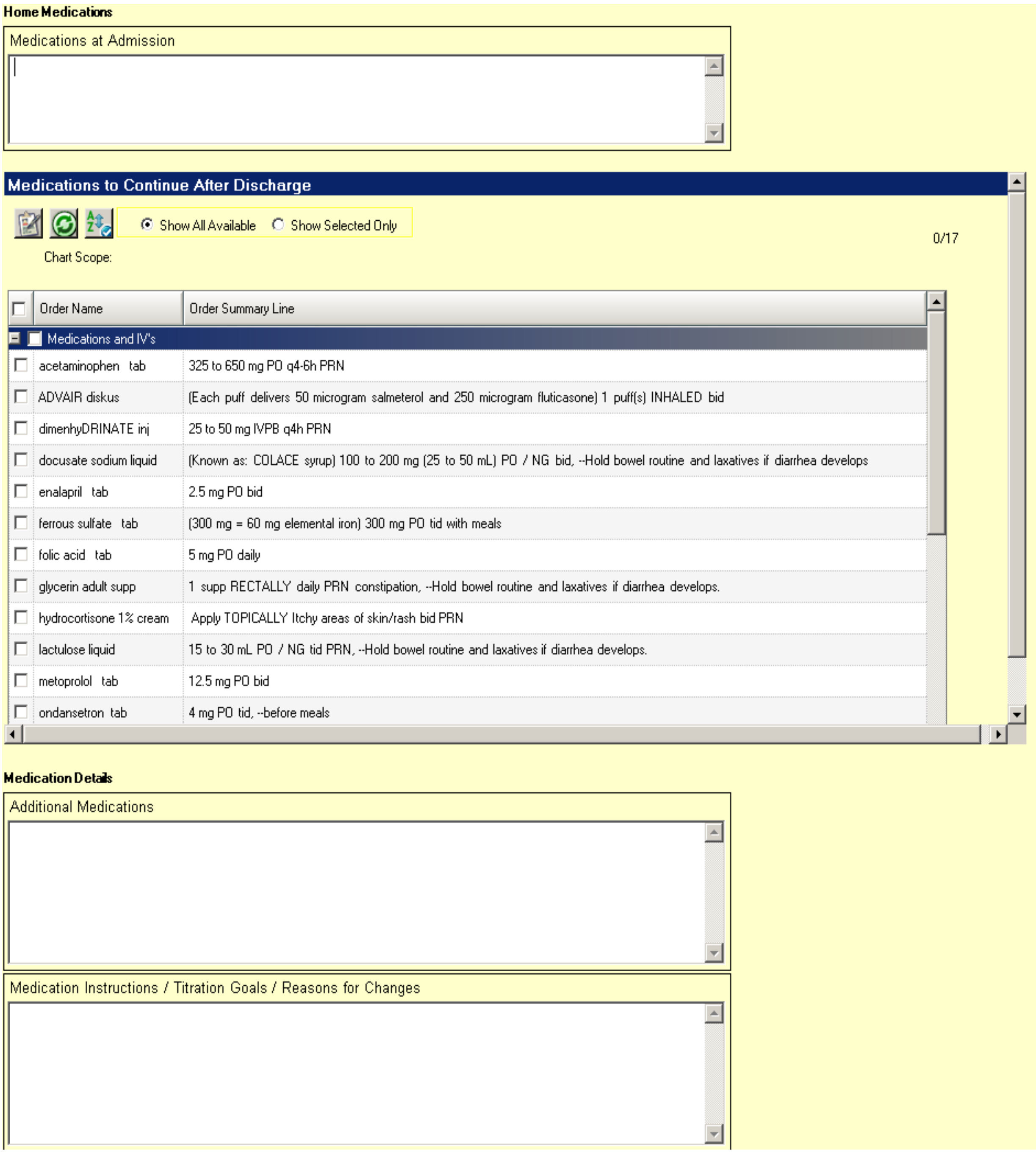


Table 11: Characteristics of included studies from the systematic review by Motamedi et al (2011) (7)

Author (Year)	Country	Population	Intervention	Comparator	Jadad Score
Afilalo et al (2007), Lang et al (2009)	Canada	Emergency	PCPs connected to system, electronic dissemination	Paper based	3
Garcia-Aymerich et al (2007)	Spain	Respiratory and Environmental Health Research Unit	Information and communication technologies platform	Standard protocols	4
Casas et al (2006)	Spain, Belgium	Respiratory and Environmental Health Research Unit	Information and communication technologies platform	Standard protocols	3
Gray et al (2000)	USA	Neonatal Intensive Care Unit	Telemedicine program	Usual care	3
Van Walraven and Rokosh (1999)	Canada	General Internal Medicine Unit	Database, posted/faxed	Dictated, posted/faxed	3
Maslove et al (2009)	Canada	General Internal Medicine Unit	Text free entry	Dictation	3
Graumlich et al (2009)	USA	General Internal Medicine Unit	E-order system plus EDCT	Handwritten	3
Kirby et al (2006)	UK	Endocrinology	EDCT with e-prescriptions	Dictation	
Branger et al (1992)	Netherlands	Two hospitals (Unit not reported)	E-dissemination	Paper based	
Callen et al (2008), Callen et al (2010)	Australia	78 bed hospital	EDCT with e-prescriptions	Handwritten	

A.2 Chapter 2

A.2.1 Search Strategy

MEDLINE search strategy (search completed on October 19, 2015)

1.	(cost adj analysis).ti,ab.
2.	exp Economics, Medical/ or exp Economics, Hospital/
3.	(economic* or price or pricing).ti,ab.
4.	(expenditure* not energy).ti,ab.
5.	value for money.ti,ab.
6.	budget*.ti,ab.
7.	return on investment.ti,ab.
8.	value proposition.ti,ab.
9.	exp Markov Chains/
10.	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9
11.	letter.pt.
12.	editorial.pt.
13.	11 or 12
14.	10 not 13
15.	exp Patient Discharge/
16.	exp Patient Discharge Summaries/
17.	(discharge or referral or transition or handoff).ti,ab.
18.	(patient adj summar*).ti.
19.	15 or 16 or 17 or 18
20.	web based.ti,ab.
21.	exp Electronics/
22.	exp Medical Records Systems, Computerized/
23.	(electronic* or computer*).ti,ab.
24.	20 or 21 or 22 or 23
25.	14 and 19 and 24

EMBASE search strategy (search completed on October 19, 2015)

1.	(cost adj analysis).ti,ab.
2.	health economics/
3.	(economic* or price or pricing).ti,ab.
4.	(expenditure* not energy).ti,ab.
5.	value for money.ti,ab.
6.	budget*.ti,ab.
7.	return on investment.ti,ab.
8.	value proposition.ti,ab.
9.	markov chains.ti,ab.
10.	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9
11.	letter.pt.
12.	editorial.pt.
13.	11 or 12
14.	10 not 13
15.	hospital discharge/
16.	(discharge or referral or transition or handoff).ti,ab.
17.	(patient adj summar*).ti.
18.	15 or 16 or 17
19.	web based.ti,ab.
20.	electronics/
21.	(electronic* or computer*).ti,ab.
22.	19 or 20 or 21
23.	14 and 18 and 22

EconLit search strategy (search completed on October 19, 2015)

1.	TI patient discharge or TI hospital discharge or TI patient referral or TI patient transition or TI patient handoff

NHSEED search strategy (search completed on October 19, 2015)

1.	Patient Discharge/
2.	(discharge or referral or transition or handoff).ti.
3.	1 or 2

Web of Science search strategy (search completed on October 19, 2015)

1.	TS=(cost near/1 analysis) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
2.	TS=(economic* or price or pricing) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
3.	TS=(expenditure* NOT energy) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
4.	TS=(value near/3 money) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
5.	TS=(budget*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
6.	TS=(return near/2 investment) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
7.	TS=(value near/1 proposition) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
8.	TS=(Markov near/1 chains) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
9.	#8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1 Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
10.	#8 OR #7 OR #6 OR #5 OR #4 OR #3 OR #2 OR #1 **Refined by:** [excluding] **DOCUMENT TYPES:** (BOOK CHAPTER OR BIBLIOGRAPHY OR MUSIC PERFORMANCE REVIEW OR DISCUSSION OR SOFTWARE REVIEW OR EXCERPT OR BOOK REVIEW OR CORRECTION OR ART EXHIBIT REVIEW OR TV REVIEW RADIO REVIEW OR REVIEW OR REPRINT OR ABSTRACT OF PUBLISHED ITEM OR DATABASE REVIEW OR EDITORIAL MATERIAL OR BIOGRAPHICAL ITEM OR HARDWARE REVIEW OR TV REVIEW RADIO REVIEW VIDEO OR RECORD REVIEW OR FILM REVIEW OR MUSIC SCORE REVIEW OR LETTER OR ITEM ABOUT AN INDIVIDUAL OR FICTION CREATIVE PROSE OR SCRIPT OR NOTE OR CORRECTION

	ADDITION OR CHRONOLOGY OR DANCE PERFORMANCE REVIEW OR NEWS ITEM OR POETRY OR THEATER REVIEW) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
11.	TI=(patient near/5 discharge) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
12.	TI=(discharge or referral or transition or handoff) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
13.	TI=(patient near/1 summar*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
14.	#12 OR #11 Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
15.	TI=(web near/1 based) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
16.	TI=(electronic* or computer*) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
17.	#15 OR #14 Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years
18.	#16 AND #13 AND #10 Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH Timespan=All years

PubMed search strategy (search completed on October 19, 2015)

1.	((cost adj analysis[Title/Abstract]) OR (economic*[Title/Abstract]) OR price[Title/Abstract] OR pricing[Title/Abstract]) OR (expenditure* not energy[Title/Abstract]) OR (value for money[Title/Abstract]) OR (budget*[Title/Abstract]) OR (return on investment[Title/Abstract]) OR (value proposition[Title/Abstract]) OR (markov chains[Title/Abstract])) AND((discharge[Title/Abstract] OR referral[Title/Abstract] OR transition[Title/Abstract] OR handoff[Title/Abstract]) OR (patient adj summar*[Title/Abstract])) AND ((web based[Title/Abstract]) OR (electronic*[Title/Abstract] OR computer*[Title/Abstract]))

A.2.2 Quality Assessment (CHEC-list of included studies)

		Kopach, R., *et al* (10)	Colsman, A., *et al* (11)	Aanesen, M., *et al* (12)	Mourad, M., *et al* (13)
1.	Is the study population clearly described?	X	X	X	X
2.	Are competing alternatives clearly described?	X	X	X	X
3.	Is a well-defined research question posed in answerable form?	X	X	X	X
4.	Is the economic study design appropriate to the stated objective?	X			
5.	Is the chosen time horizon appropriate in order to include relevant costs and consequences?	X		X	
6.	Is the actual perspective chosen appropriate?	X			
7.	Are all important and relevant costs for each alternative identified?	X	X	X	X
8.	Are all costs measured appropriately in physical units?	X	X	X	
9.	Are all costs valued appropriately?	X		X	
10.	Are all important and relevant outcomes for each alternative identified?	X	X	X	X
11.	Are all outcomes measured appropriately?	X	X	X	
12.	Are outcomes valued appropriately?	X	X	X	
13.	Is an incremental analysis of costs and outcomes of alternatives performed?	X			
14.	Are all future costs and outcomes discounted appropriately?	X		X	
15.	Are all important variables, whose values are uncertain, appropriately subjected to sensitivity analysis?	X			
16.	Do the conclusions follow from the data reported?	X	X	X	X
17.	Does the study discuss the generalizability of the results to other settings and patient/client groups?	X			X

18.	Does the article indicate that there is no potential conflict of interest of study researcher(s) and funder(s)?	X	X		
19.	Are ethical and distributional issues discussed appropriately?				

A.3 Chapter 3

A.3.1 Amortization Calculation

$$A = P[\frac{r(1+r)^n}{(1+r)^n - 1}]$$

Monthly payment over 3 years with a 5% annual interest rate:

P=$127,575.00

R=%1 per year/12 months = 0.0833%

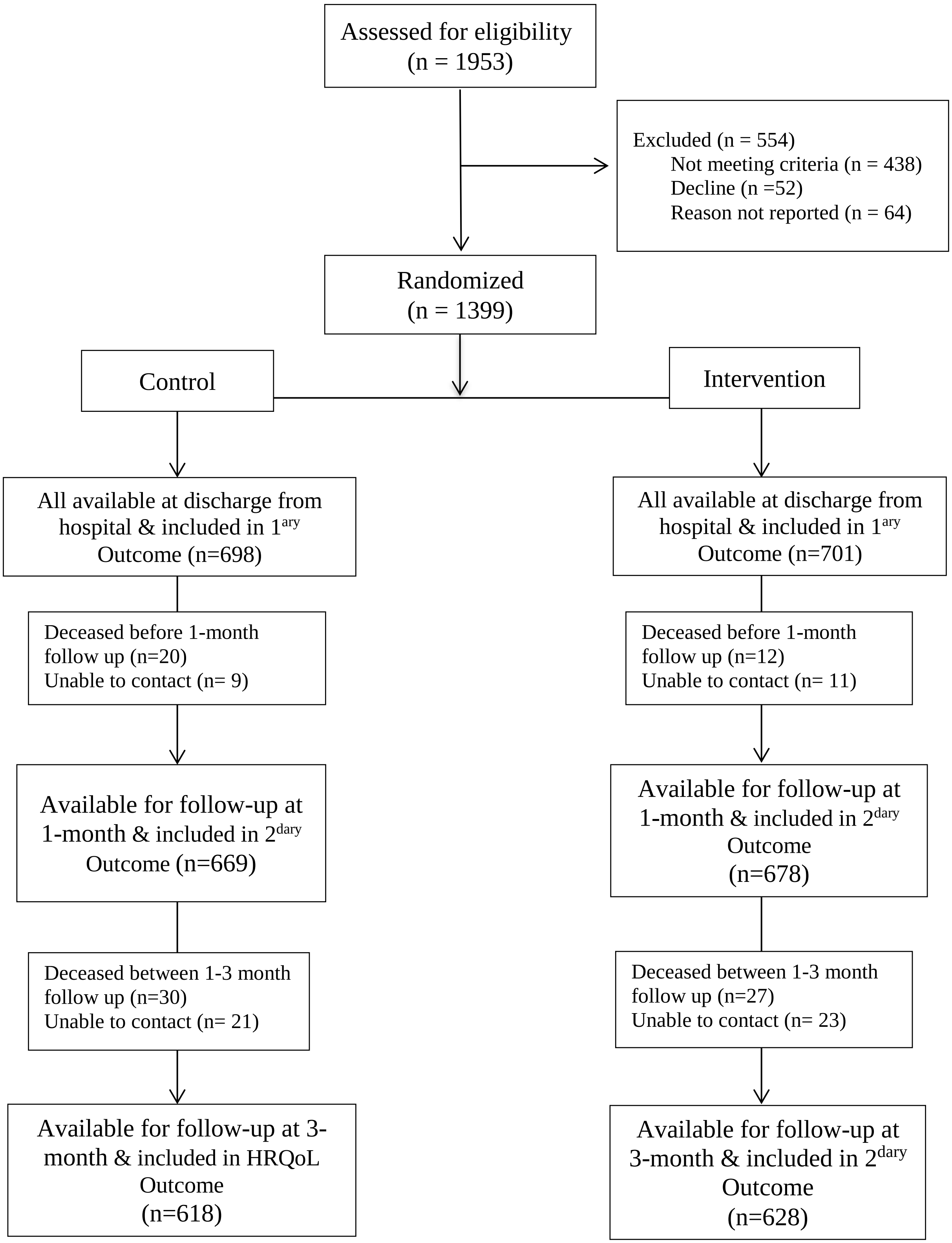
n=3 years * 12 months = 36 periods

A=Payment amount: **$3598.65**

Cost per person: $3598.65/(9*30) = **$13.33**

Total for treatment arm: $13.33*679 = 9,051.07

Figure 7: CONSORT flow chart (From Santana et al.)



A.3.2 Calculation of Average Cost of Discharge per Patient in Usual Care – Scenario Analysis

Scenario 1: Non-speech recognition system

Estimated Number of Transcriptionists:
Monthly Salary (excluding overtime) = $275,531.00
Total Hourly Salary = [($275,531.00/4 weeks)/5 days per week]/8 hours per day= $1,722.07
Approximate hourly wage per transcriptionist = $4.11 dollars per minute of transcription * 12.6 min of transcription per hour = $51.77
Number Transcriptionists = $1,722.07/$51.77 = 33.25 ~ **33 transcriptionists**

Average Number of Transcriptions Completed "In-House" per Month:
Discharge summaries transcribed per hour = 12.6 min of dictation transcribed per hour/10.86 min of dictation per discharge = 1.16 discharge summaries transcribed per hour
Number discharges completed per month per transcriptionist = 1.16 per hour * 8 hours * 5 days * 4 weeks = 185.6 ~ 186
Total discharge summaries completed total (33 transcriptionists) = 186 * 33 = **6138 discharge summaries completed "in-house" per month**

Average Number of Transcriptions Completed through Outsourcing per Month:
Outsourcing cost per patient = $22.28
Number of patients outsourced = $28,753.80 monthly outsourcing cost/$22.28 = 1290.57 ~ **1291 discharge summaries completed through out-sourcing**

Total Number of Transcriptions Completed per Month = 6138 + 1291 = **7429**
Average cost per patient = Total Monthly Cost = ($1421 + $28,753.80 + $309,727.00)/7429 = **$45.75**

Scenario 2: Speech recognition system

Estimated Number of Transcriptionists:
Monthly Salary (excluding overtime) = $272,929.00
Total Hourly Salary = [($272,929.00/4 weeks)/5 days per week]/8 hours per day= $1,705.81
Approximate hourly wage per transcriptionist = $3.66 dollars per minute of transcription * 15.7 min of transcription per hour = $57.46
Number Transcriptionists = $1,705.81/$57.46 = 29.69 ~ **30 transcriptionists**

Average Number of Transcriptions Completed "In-House" per Month:
Discharge summaries transcribed per hour = 15.7 min of dictation transcribed per hour/10.86 min of dictation per discharge = 1.45 discharge summaries transcribed per hour
Number discharges completed per month per transcriptionist = 1.45 per hour * 8 hours * 5 days * 4 weeks = 232
Total discharge summaries completed total (33 transcriptionists) = 232*30 = **6960 discharge summaries completed "in-house" per month**

Average Number of Transcriptions Completed through Outsourcing per Month:

Outsourcing cost per patient = $22.28
Number of patients outsourced = $28,522.35 monthly outsourcing cost/$22.28 = 1280.18 ~ **1280 discharge summaries completed through out-sourcing**

Total Number of Transcriptions Completed per Month = 6960 + 1280 = **8240**
Average cost per patient = Total Monthly Cost = ($29,224.00 + $28,522.35 + $276,366.00)/8240 = **$40.55**