Chapter 18

Value for Money in eHealth

Meta-synthesis of Current Evidence

Francis Lau

18.1 Introduction

Over the years a number of systematic reviews on studies that evaluated the economic return of eHealth investments have been published in the literature. Notable examples are the review on the financial effects of HIT by Low et al. (2013) based on 57 studies, the economics of HIT in medication management by O'Reilly, Tarride, Goeree, Lokker, and McKibbon (2012) based on 31 studies, and the scoping review of HIS on value for money by Bassi and Lau (2013) based on 42 studies. At a glance, these review findings seem favourable with over half of the studies showing positive economic returns. However, one should be mindful the studies were based on a diverse set of economic evaluation methods ranging from cost, outcome to full economic analysis done through modelling and field settings under different assumptions. Also the authors of these reviews have stressed the limitations of their findings. They include the heterogeneity of the eHealth systems examined, lack of detail on the system features, weak study designs with diverse costing/valuation methods and measures, and difficulty in generalizing the results. More importantly, not all of the studies were full economic evaluations and, thus, it was difficult to determine if the reported benefits were worth the investments. Few studies included the incremental cost of producing an extra unit of outcome and the long-term effect of the eHealth system.

In this chapter, three economic evaluation case studies that have been reported in the literature are presented to demonstrate value for money in eHealth. The three examples are: (a) a meta-synthesis of published eHealth economic reviews (section 18.2); (b) the cost-effectiveness and utility of computer-supported diabetes care in Ontario, Canada (section 18.3); and (c) the budget impact and

sustainability of system-wide human immunodeficiency virus (HIV) testing in the Veterans Affairs (VA) Administration in the United States (section 18.4). This is followed by a summary of the current state of evidence on eHealth economic evaluation for those involved in eHealth investment decisions (section 18.5).

18.2 Evidence on Value for Money in eHealth

This section examines the results of a meta-synthesis of the three published eHealth economic evaluation reviews by Low et al. (2013), Bassi and Lau (2013), and O'Reilly, Tarride, et al. (2012). The intention was to combine these reviews to make sense of the current state of evidence on value for money in eHealth investments. To do so, first the three original reviews were reanalyzed to reconcile the mixed findings. Then the focus turned to the full economic evaluation studies from these reviews that were published between 2000 and 2010 in order to gain insights on the economic return for specific types of eHealth systems.

18.2.1 Synopsis of Economic Review Findings

The review by Low and colleagues (2013) found that 75.4% (or 43 out of 57) of their studies had reported financial benefits in the form of revenue gains and cost savings to stakeholders. The eHealth systems in question were: 42.1% (24/57) CPOE/CDS (computerized provider order entry/clinical decision support); 45.6% (26/57) EHR; 8.8% (5/57) HIE; and 3.5% (2/57) combined. The proportions of systems with reported benefits included: 88.4% (14/17) outpatient EHR; 69.2% (9/13) outpatient CPOE/CDS; 60.0% (6/10) inpatient CPOE/CDS; and 75.0% (3/4) Emergency Department HIE.

The review by Bassi and Lau (2013) found that 69.7% (or 23 out of 33) of their high-quality studies (quality score ≥ 8/10) had reported positive returns. The eHealth systems in question were: 21.2% (7/33) primary care EMR; 18.2% (6/33) CPOE; 15.2% (5/33) medication management; 15.2% (5/33) immunization; 12.1% (4/33) HIS; 9.1% (3/33) disease management; 6.1% (2/33) clinical documentation; and 3.0% (1/33) HIE. The proportions of systems with positive returns included: 71.4% (5/7) primary care EMR; 50.0% (3/6) CPOE; 100% (5/5) medication management; 60.0% (3/5) immunization; 75.0% (3/4) HIS; 100% (3/3) disease management; and 100% (1/1) HIE. The remaining two clinical documentation systems had inconclusive results.

The review by O'Reilly, Tarride, et al. (2012) had 31 studies but only narrative descriptions were reported because of the heterogeneity of the settings, systems and methods involved. While the review was on medication management, the HITS evaluated varied and were mostly CPOE, CDS, MAR (medication administration record), and combined systems (67.7% or 21/31 studies) with the remaining as barcode, EMR or cardiopulmonary resuscitation (CPR), surveillance and ePrescribing systems. The authors did not summarize the proportion of studies with economic benefits but a tabulation from the narrative tables in the review showed that 67.7% or 21 out of 31 studies had reported some cost benefits.

18.2.2 Meta-synthesis of Full Economic Evaluation Studies

Combined, the three reviews had a total of 121 evaluation studies published during the period between 1993 and 2010. To make sense of the review findings, a reanalysis of all of the studies was conducted by reconciling for duplicates, selecting only those published in English between 2000 and 2010, then grouping them by economic analysis method. This reanalysis led to a combined list of 81 unique studies, of which only 19 or 23.5% were considered full economic evaluation. These 19 studies were then synthesized to provide an economic evidence base for eHealth systems in primary care EMR, medication management, CPOE/CDS, institutional HIS, disease management, immunization, documentation and HIE, as defined by Bassi and Lau (2013).

A summary of the 19 studies by eHealth system, author-year, time frame, options, cost, outcome, comparison method, results and interpretation is shown in the Appendix. Of these 19 studies, seven were on primary care EMRs, three on medication management, three on CPOE/CDS, two on institutional HIS, and one each on disease management, immunization, documentation and HIE, respectively. For designs, 78.9% (15/19) were field studies and 21.1% (4/19) were simulations. For methods, 73.7% (14/19) of the studies were cost-benefit, 21.1% (4/19) cost-effectiveness, and 5.2% (1/19) cost-consequence analysis. Two studies also included cost-minimization as a second method. For valuation, 52.6% (10/19) of the studies included some type of discounting and/or inflation to determine the present dollar value. Of the 19 studies, only 36.9% (7/19) included one- or multi-way sensitivity analysis, 21.1% (4/19) reported the incremental cost-effectiveness ratio (ICER), and 5.3% (1/19) included quality-adjusted life years (QALY).

For results, there were positive returns on investment in 100% (7/7) of the primary EMR, 66.7% (2/3) of CPOE/CDS, 100% (2/2) of institutional EHR, and 100% for each of the disease management (1/1), immunization (1/1) and HIE (1/1) systems. The three medication management systems and the one documentation system did show positive returns but only when specific conditions were met. A closer examination of the results revealed that the positive returns from the primary care EMR studies were mainly productivity-related in terms of cost savings and increased revenues, with little mention of tangible improvement in health outcomes. One CPOE study had mixed results in that the simulated operating margins from CPOE adoption were positive over time for large urban hospitals but for not rural or critical access hospitals. The three medication management studies were inconclusive as they were dependent on certain contextual factors. For instance, Wu, Laporte, and Ungar (2007) showed an incremental cost-effectiveness ratio (ICER) of $12,700 per adverse drug event (ADE) averted. That translated to 32.3 ADEs averted per year or 261 events averted over 10 years, but the estimates depended on the base rate of adverse drug events, system and physician costs and the ability to reduce ADEs. Fretheim, Aaserud, and Oxman (2006) found the cost of thiazide intervention to be twice the cost savings in year-1 before modest savings could be projected in year-2 by expand-

ing the intervention into a national program. Similarly, the clinical documentation study by Kopach, Geiger, and Ungar (2005) showed ICER of $0.331 per day in average discharge note completion time, depending upon physician utilization volume and length of the study.

Based on the results of this small set of full economic analysis studies there is some evidence to suggest value for money in eHealth investments in selected healthcare domains and types of systems. However, the number of studies is small and caution is needed when generalizing these results to other settings.

18.3 Computer-supported Diabetes Care in Ontario

This section presents a set of economic evaluation modelling and field studies on diabetes care done in the Canadian Province of Ontario over the past 15+ years that began around the year 1999. These include: (a) the application of the Ontario Diabetes Economic Model (ODEM) in the COMPETE-II randomized trial; and (b) a mega-analysis on optimizing chronic disease management that includes electronic tools for diabetes care. These studies are described below.

18.3.1 Application of ODEM in COMPETE-II Trial

The ODEM is a simulation model that uses a set of parametric risk equations, based on specific patient characteristics, to predict the cost and occurrence of diabetes-related complications, life expectancy and quality-adjusted life years (QALYS) over a 40-year time horizon. The ODEM is an adaptation of the United Kingdom Prospective Diabetes Study (UKPDS) Outcomes Model, which was developed with data from the UKPDS conducted as a randomized trial in the 1970s (Clarke et al., 2004).

Holbrook and colleagues (2009) conducted the COMPETE-II study in Ontario as a pragmatic randomized trial during 2002 and 2003. Its objective was to determine if electronic decision support and shared information with diabetic patients could improve their care in the community setting. The study was conducted in three Ontario regions with 46 primary care practices and adult patients under their care. The study results were then applied as inputs to the ODEM in a modelling study to estimate the long-term quality of life and cost implications (O'Reilly, Holbrook, Blackhouse, Troyan, & Goeree, 2012). The key aspects of the two studies are summarized below in terms of the diabetes cohort, intervention, economic analysis and projected benefit.

> *Diabetes Cohort* – The study had 511 adult type-2 diabetic patients, with 252 randomized to the intervention group and 258 to the control group. The mean follow-up time was 5.9 months and the median time since diagnosis of diabetes was 5.9 years. Key risk factors from the trial were used as input to the ODEM such as HbA1c (glycated hemoglobin test), systolic blood pressure, cholesterol and smoking status. The costs of resource use and diabetes-related

complications in the ODEM were derived from a prospective cohort of 734,113 diabetic patients over a 10-year period representing 4.4 million patient-years in Ontario.

Intervention – An individualized electronic decision support (DS) and reminder system for diabetes care was implemented in three Ontario regions for use by 46 primary care practices over a one-year period. The intervention included a Web-based diabetes tracker template for shared access by providers and patients, an automated phone reminder for patients, and a colour tracker page mailed to patients. The diabetes tracker template was interfaced with the EMR and allowed the display and monitoring of 13 risk factors, specifically blood pressure, cholesterol, HbA1c, foot exam, kidney, weight, physical activity, smoking, eye exam, acetylsalicylic acid or equivalent, ACE inhibitors, and flu shot. The automated phone reminder system prompted patients every month to follow up on medications, labs and physician visits. The colour tracker page was mailed to patients four times a year and was to be taken to physician appointments.

Economic Analysis – The long-term cost-effectiveness of the shared DS and reminder system was examined. The respective economic evaluation components are summarized below.

- Perspective – Ontario Ministry of Health;
- Options – A shared DS and reminder system versus usual care;
- Time Frame – 40-year time horizon after the 12-month study in 2002-03, assuming a one-year treatment effect at 5% discount rate in 2010 Canadian dollars;
- Input Costs – Program implementation costs and projected diabetes complications. Program costs included tracker development and testing, ongoing project management, and required IT infrastructure;
- Outcomes – Intermediate outcomes (HbA1c, blood pressure, cholesterol and smoking), life years, quality-adjusted life years (QALYS), incremental costs, and ICER;
- Comparison of Options – Cost-effectiveness analysis to compare lifetime effects of DS and reminder system versus usual care in expected costs per patient, life years, QALYS and ICER. Sensitivity analysis to compare lifetime effects of program and treatment effect duration of one, five and 10 years, and discount rates of 0%, 3% and 5%.

Projected Benefit – The intervention reduced HbA1c by 0.2 and systolic blood pressure by 3.95 mmHG, and an overall relative risk

reduction of 14% in the need for amputation. The total cost of the intervention was $483,699, at a mean lifetime cost of $1,912 per patient receiving the intervention. The ODEM estimated the disease management costs to be $61,340 and $61,367 for the intervention and control groups, respectively, at an incremental cost of –$26 per patient. The avoidance of complications would gain an additional 0.0117 QALYs, and an estimated ICER of $156,970 per life year and $160,845 per QALY. Sensitivity analysis showed an increase of 260% in QALYs from 0.0117 to 0.0421 when patients were treated for five years due to reduced downstream complications, at an ICER of $186,728. When patients were treated for 10 years there was a sixfold increase in QALYs gained, at an ICER of $173,654. Overall, the intervention led to slight improvement in short-term risk factors and moderate improvement in long-term health outcomes. To do so, the intervention had to be highly efficient and effective in its costs and care processes.

18.3.2 Optimizing Chronic Disease Management Mega-analysis

In 2013 Health Quality Ontario (HQO) published a mega-analysis series drawn from 15 reports on the economic aspects of community-based chronic disease management (CDM) interventions (HQO, 2013). The chronic diseases examined were diabetes, chronic obstructive pulmonary disease (COPD), coronary artery disease, and congestive heart failure. The CDM interventions included discharge planning, continuity of care, in-home care, specialized nursing practice, and electronic tools (eTools) for health information exchange (HIE). The eTools for HIE component of this mega-analysis in diabetes care is summarized below in terms of the diabetes cohort, intervention, economic analysis and projected benefit.

Diabetes Cohort – Adult patients with type-2 diabetes-related physician visits or one hospital admission within two years between 2006 and 2011 were included as the Ontario cohort. For each patient, their resource use and mean 90-day total costs by sector were estimated from the Ontario administrative databases. These included emergency department visits, acute inpatient and same-day surgery costs, other hospital costs, long-term care, home care and physician visits, lab costs and drug costs. The EQ-5D (European Quality of Life 5 Dimensions) values were used as the utility estimates for changes in quality of life from hospitalizations during the study period. The mean EQ-5D value of 0.77 derived from 3,192 patients in the UKPDS (Clarke, Gray, & Holman, 2002) was used as the baseline utility estimate for the Ontario cohort. The mean EQ-5D value of 0.54 was used as a proxy measure for hospitalization, based on the study on severe hypoglycemia in diabetics by Davis et al. (2005). Patients in the Ontario cohort who

were hospitalized were assigned the utility value of 0.54 over their average length of stay. For the intervention group, a 0.85 relative difference in hospitalization from an eTools for HIE field trial by Kahn, MacLean, and Littenberg (2010) was applied as a result of improved quality of life, thereby reducing the proportion of patients hospitalized.

Intervention – The Vermont Diabetes Information System (VDIS) developed by MacLean, Littenberg, and Gagnon (2006) was used as the model eTool for HIE intervention. The VDIS is a decision support system that sends lab results, reminders and alerts to primary care providers and their patients with diabetes. Quarterly population reports were also available to providers for peer comparison. A randomized trial by MacLean, Gagnon, Callas, and Littenberg (2009) showed that VDIS improved lab monitoring of diabetic patients in primary care but not physiologic control. For cost, the VDIS vendor quoted a one-time software cost of $5,000 and an annual maintenance cost of $2,500 per laboratory. The annual cost to receive VDIS information was $6,000 per physician and $48 per patient in 2012 Canadian dollars. The per-patient costs were dependent on physician roster size and disease prevalence. Since no eTools for HIE were in regular use in Ontario at the time of the mega-analysis, the proportion of diabetic patients that could benefit from HIE was assumed to be 100%.

Economic Analysis – The projected cost-effectiveness of the modelled eTools for HIE in community-based care were examined. The respective economic evaluation components are summarized below.

- Perspective – The Ontario provincial health ministry level (i.e., Ministry of Health and Long-Term Care);
- Options – Hypothetical adoption of VDIS as the eTools for HIE versus usual care with no HIE;
- Time Frame – A five-year horizon with an annual 5% discount rate inflated to 2012 Canadian dollars; duration of benefit assumed to be 32 months based on the literature;
- Input Costs – Estimated resource use costs with or without hospitalization for the Ontario cohort based on administrative data over a five-year period. Estimated one-time intervention costs covered and ongoing VDIS costs for 211 labs, 11,902 physicians and 85 diabetic patients per physician;
- Outcomes – Proportion of hospitalized patients based on severe hypoglycemia as a proxy measure from the literature and QALYS

with or without hospitalization based on EQ-5D values as utility estimates from the literature;
- Comparison of Options – Cost-effectiveness analysis to compare eTools with usual care options in cost per patient, QALYs per patient, and ICER. Sensitivity analysis to compare changes in relative difference of hospitalization and emergency department visits, and marginal ongoing costs in the intervention group.

Projected Benefit – The cost-effectiveness analysis showed that the cost per patient was $29,889 with eTools versus $30,226 with usual care. The QALYs per patient was 2.795 with eTools versus 2.789 with usual care. The ICER was –$337 per patient. The sensitivity analysis showed the model was sensitive to changes in resource use and intervention cost. For instance, a relative difference of 0.75 in hospitalization for the intervention would change the ICER to –$1,228, where a relative difference of 0.95 would change the ICER to $654. A marginal cost of $74 in ongoing cost for the intervention would change the ICER to –$724, but a marginal cost of $233 would change the ICER to $639. Overall, the intervention was found to be less costly and more effective when compared with usual care.

18.4 System-wide HIV Testing in Veterans Affairs (VA) Administration

In 1998 the United States VA Administration launched the Quality Enhancement Research Initiative (QUERI) to improve the performance of the VA healthcare system and the consequent quality of care for its veterans (Smith & Barnett, 2008). In that initiative, QUERI researchers collaborated with VA leaders and staff to implement evidence-based practice as the routine standard of care through a six-step process:

1 Identify high-risk/volume diseases or problems.

2 Identify best practices.

3 Identify deviations from current practices and outcomes.

4 Identify and implement interventions to promote best practices.

5 Document that best practices improved outcomes.

6 Document that outcomes were associated with improved health-related quality of life.

For step-4 above, the implementation efforts followed a sequence of phases from a single-site pilot project to a small-scale multisite trial, followed by a large-scale multi-region trial to a final system-wide rollout. An integral part of the initiative was the use of policy cost-effectiveness and budget impact analysis in single-site and multisite trials to determine the economic return. This section describes a case study on HIV testing at the VA Administration in terms of the multi-component intervention program, different implementation phases it went through over the years, and budget impact analysis done on the program.

18.4.1 Multi-component Intervention Program

The multi-component intervention was made up of computerized decision support, audit-feedback, provider activation and organizational level change (Goetz et al., 2008). The computerized decision support was a real-time clinical reminder that identified patients at increased risk for HIV infections and prompted healthcare providers to offer HIV testing to these patients. The clinical reminder was triggered by the presence of a set of predefined criteria such as prior Hepatitis B or C infection, sexually transmitted disease, drug use, homelessness and specific behavioural risk factors (e.g., excessive alcohol use, multiple sexual partners, body piercing). These data elements were automatically extracted from the VA EMR during the patient visit. Once triggered, the provider had to address the reminder by ordering an HIV test, asking the test to be done elsewhere, recording that the patient was either not competent to consent to testing or had refused testing.

An audit-feedback system was developed to inform providers of their performance in HIV evaluation and testing rates of at-risk patients at the clinic level. The reports were distributed to clinical leaders and clinic managers via e-mail on a quarterly basis. Provider activation included the use of academic detailing, social marketing and educational materials to engage both providers and patients in the initiative. Academic detailing involved one-on-one sessions in person and ad-hoc site visits with project staff to discuss the need for and benefits of HIV testing. Social marketing involved the recruitment of physician and nurse leaders to encourage HIV testing at the clinic. Educational materials included information handouts, pocket cards and posters to inform providers and patients on the need and criteria for, and process and implications of HIV testing. Change at the organizational level involved the removal of barriers to HIV testing, such as the inclusion of streamlined pretest counselling that only took two to three minutes, and post-test phone notification and brief counselling of negative test results.

18.4.2 Program Implementation and Evaluation

Goetz and colleagues (2008) conducted a pre-post intervention study from 2004 to 2006 to determine if the multi-component intervention program would increase the rate of HIV testing. Five VA facilities took part in the study with two

receiving the intervention and three as controls. The HIV testing rate and the number of newly diagnosed cases in the year before and after implementing the intervention were compared. Patient, provider and facility-level factors that could influence testing performance were also examined. These included patient subgroups with different demographics and risk factors, proportions of at-risk patients tested by primary providers, as well as the prevalence of at-risk patients and annual patient load at the facility. The results showed 36,790 untested patients with HIV risk factors from the intervention sites and 44,577 patients from the control sites were considered in the study. The adjusted rate of HIV testing at the two intervention sites increased from 4.8% to 10.8% and from 5.5% to 12.8%, and the number of newly diagnosed cases increased from 15 to 30 after implementing the intervention. There was no change in the control sites during the same period. Overall the intervention was considered effective in increasing the HIV testing rate and the detection of new cases.

Sustainability of the Intervention – Goetz et al. (2009) evaluated the sustainability of increased HIV testing after implementing the multi-component intervention program in 2005. The intervention was implemented in month-1 of the intervention year 2005 then continued for the subsequent 11 months. During the intervention year the study team supported the provider activation component of the intervention that included academic detailing, social marketing, and provision of educational materials. In year-2, or the sustainability year, the responsibility for provider activation was transferred to the clinic. During this period the clinical reminders continued to be used, the quarterly feedback reports were managed by clinical leaders, and provider education activities were reduced and merged with regular staff meetings. Further organizational changes broadened the number of providers who could order the test, eased the documentation requirements and continued with the pretest and post-test counselling. The results showed the monthly adjusted testing rate increased from 2% at baseline to 6% by the end of the intervention year. Then the rate declined to 4% by the end of the sustainability year. The testing rate for persons newly exposed to the intervention increased during the intervention and sustainability years. The attenuation effect in the sustainability year was caused by the increase in the proportion of visits by untested patients despite prior exposures to the intervention. The percentage of patients who received HIV testing was 5.0% in the pre-intervention year, 11.1% in the intervention year, and 11.6% in the sustainability year. Overall, the intervention was considered sustainable, especially in patients during their early contacts with the healthcare system.

Scalability of the Intervention – Goetz and colleagues (2013) also evaluated the scalability of the multi-component intervention in routine HIV testing and the level of support needed. A one-year three-arm quasi-experimental study was conducted with central support, local support, and no support (i.e., control) provided to different VA primary care sites in three geographic regions. All sites had access to the real-time clinical reminder system. With central support, the study team provided quarterly audit-feedback reports, provider activation and ongoing support including site visits. With local support, the sites had only a single conference call 30 days after the initial site visit. The control sites had no contact with the study team. The clinical reminder was initially risk-based for all sites in the first six months of the study, then became routine for all patients in the following six months. In phase-1, the adjusted rate of risk-based testing increased by 10.1%, 5.6% and 0.4% in the central, local and control sites, respectively. In phase-2, the adjusted rate of routine testing increased by 9.2%, 6.3% and 1.1% in the central, local and control sites. By the end of the study, 70% to 80% of VA patients had been offered an HIV test. Overall, the multi-component intervention program was considered scalable in reaching the goal of all VA patients being aware of their HIV status as part of routine clinical visits.

18.4.3 Budget Impact Analysis

Anaya, Chan, Karmarkar, Asch, and Goetz (2012) conducted a budget impact study to examine the facility-specific costs of HIV testing and care for newly identified HIV patients. The study was based on the multi-component HIV intervention program discussed above, that was implemented as a pre-post quasi-experimental trial in five Veterans Health Administration facilities (Goetz et al., 2008). A budget impact model was developed to estimate the costs of HIV testing that included the costs of pretest counselling, HIV testing rates, and treatment of identified HIV patients. The budget impact model, intervention, economic analysis and projected benefits are summarized below.

Budget Impact Model – The model was developed to estimate the costs of HIV testing in a single VA facility in the primary care setting. Two HIV providers were consulted to establish relevant model end points. They covered physician and nurse staffing costs, laboratory costs, and the costs of antiretroviral therapy (ART) for different levels of HIV disease progression based on Cluster of Differentiation 4 (CD4) counts. The model included quarter-to-quarter changes in patient status, loss to follow-up and deaths that occurred in a period. It covered the costs of tested and untested patients of known and unknown HIV status who received care in

a single facility over eight three-month periods. A hypothetical cohort of 20,000 adult patients was used, with a prevalence of 9.2% as having already been tested, 200 as known HIV patients under care, three minutes of extra nursing time, and a 2.1% annual baseline HIV testing rate in untested patients.

Intervention – The multi-component intervention program consisted of a real-time electronic clinical reminder for HIV testing, audit-feedback reports, provider activation and patient-provider education.

Economic Analysis – The budget impact of expanded HIV testing in a primary care setting were examined. The respective economic evaluation components are summarized below.

- Perspective – The integrated VA healthcare system that offer both HIV testing and care;
- Options – Expanded HIV testing rate of 15% versus baseline rate of 2.1%;
- Time Frame – A two-year horizon in eight three-month quarterly periods;
- Input Costs – Personnel and laboratory costs, and ART costs from different levels of HIV disease progression based on CD4 count, tracked on a quarterly basis;
- Outcomes – HIV testing rates, number and percent of HIV-positive patients at different CD4 levels;
- Comparison of Options – Budget impact on expanded HIV testing from 2.1% to 15% at 0.45% positive test rate; sensitivity analysis with HIV testing rates from 15% to 30%, positive test rate from 0.45% to 1%, and pretest nursing time activities from three to five minutes.

Projected Benefit – The expansion of HIV testing from 2.1% to 15% annually led to the identification of 21 additional HIV-positive patients over two years at a cost of $290,000. Over 60% of this cost was to provide ART to newly diagnosed patients. Quarterly ART costs increased from $10,000 to more than $60,000 over two years with more HIV patients identified and treated with ART. In sensitivity analysis, serodiagnostic and annual HIV testing rates had the greatest cost impact. Overall, expanded HIV testing led to increased initial costs, mostly due to ART treatment for new patients. Using a $50,000 per QALY threshold, expanded HIV testing was cost-effective based on a total cost of $80,000 over two years for testing, and $290,000 for testing and care for 21 additional HIV patients.

18.5 Summary of Economic Evidence in eHealth

Overall, our meta-synthesis of the three published eHealth economic evaluation reviews showed that there is value for money in eHealth investment. However, the evidence varied depending on the domains, contexts and systems involved. This evidence is strong in primary care EMR as all seven full economic analysis studies had positive returns. For CPOE/CDS, institutional EHR, disease management, immunization and HIE systems, while there is evidence of positive returns it is much weaker since they are only based on a small number of modelling and field studies. For medication management and documentation systems, the evidence is weak to inconclusive since the positive return is contingent on the interplay of different socio-organizational, technical and external factors.

The development and validation of the ODEM and its application in the COMPETE-II and HIE studies in Ontario, Canada showed that computer-supported diabetes care could be cost-effective but required a great deal of effort to implement and maintain the interventions. With the electronic diabetes tracker, there was a modest benefit in achieving process outcome targets in the short term, and some gain in QALYS with reduced complications in the long term. However, the projected economic return was contingent on the precision of the ODEM parameter estimates such as the disease prevalence, resource use and costs, complication rates, and provider EMR adoption behaviours. The HIE modelling study was cost-effective in sharing patient information but it assumed 100% adoption of the eTools by all primary care providers in the province. Similarly, the multi-component HIV testing program in Veterans Affairs Administration in the United States showed that computerized HIV testing was cost-effective when combined with patient-provider activation and organizational policies. Once implemented, the risk-based testing program was shown to be sustainable with more streamlined support and eventually scalable as a routine practice in the organization. The ICER and gain in QALYS were considered good return on value.

References

Anaya, H. D., Chan, K., Kamarkar, U., Asch, S. M., & Goetz, M. B. (2012). Budget impact analysis of HIV testing in the VA healthcare system. *Value in Health, 15*(8), 1022–1028.

Bassi, J., & Lau, F. (2013). Measuring value for money: A scoping review on economic evaluation of health information systems. *Journal of American Medical Informatics Association, 20*(4), 792–801.

Clarke, P., Gray, A., & Holman, R. (2002). Estimating utility values for health states of type 2 diabetic patients using the EQ-5D (UKPDS 62). *Medical Decision Making, 22*(4), 340–349.

Clarke, P. M., Gray, A. M., Briggs, A., Farmer, A. J., Fenn, P., Stevens, R. J., … UK Prospective Diabetes Study (UKDPS) Group. (2004). A model to estimate the lifetime health outcomes of patients with type 2 diabetes: the United Kingdom Prospective Diabetes Study (UKPDS) outcomes model (UKPDS no. 68). *Diabetologia, 47*(10), 1747–1759.

Davis, R. E., Morrissey, M., Peters, J. R., Wittrup-Jensen, K., Kennedy-Martin, T., & Currie, C. J. (2005). Impact of hypoglycaemia on quality of life and productivity in type 1 and type 2 diabetes. *Current Medical Research and Opinion, 21*(9), 1477–1483.

Fretheim, A., Aaserud, M., & Oxman, A. D. (2006). Rational prescribing in primary care (RaPP): economic evaluation of an intervention to improve professional practice. *PLoS Medicine, 3*(6), e216.

Goetz, M. B., Hoang, T., Bowman, C., Knapp, H., Rossman, B., Smith, R., … Asch, S. M. (2008). A system-wide intervention to improve HIV testing in the Veterans health administration. *Journal of General Internal Medicine, 23*(8), 1200–1207.

Goetz, M. B., Hoang, T., Henry, R., Knapp, H., Anaya, H. D., Gifford, A. L., & Asch, S. M. (2009). Evaluation of the sustainability of an intervention to increase HIV testing. *Journal of General Internal Medicine, 24*(12), 1275–1280.

Goetz, M. B., Hoang, T., Knapp, H., Burgess, J., Fletcher, M. D., Gifford, A. L., & Asch, S. M. (2013). Central implementation strategies outperform local ones in improving HIV testing in Veterans healthcare administration facilities. *Journal of General Internal Medicine, 28*(10), 1311–1317.

Health Quality Ontario. (2013). Optimizing chronic disease management mega-analysis: Economic evaluation. *Ontario Health Technology Assessment Series, 13*(13), 1–148.

Holbrook, A., Thabane, L., Keshavjee, K., Dolovich, L., Bernstein, B., Chan, D., … Gerstein, H. (2009). Individualized electronic decision support and reminders to improve diabetes care in the community: COMPETE II randomized trial. *Canadian Medical Association Journal, 181*(102), 37–44.

Jones, S. S., Rudin, R. S., Perry, T., & Shekelle, P. G. (2014). Health information technology: An updated systematic review with a focus on meaningful use. *Annals of Internal Medicine, 160*(1), 48–54.

Khan, S., MacLean, C. D., & Littenberg, B. (2010). The effect of the Vermont diabetes information system on inpatient and emergency department use: Results from a randomized trial. *Health Outcomes in Research in Medicine, 1*(1), e61–e66.

Kopach, R., Geiger, G., & Ungar, W. J. (2005). Cost-effectiveness analysis of medical documentation alternatives. *International Journal of Technology Assessment in Health Care, 21*(1), 126–131.

Low, A. F. H., Phillips, A. B., Ancker, J. S., Patel, A. R., Kern, L. M., & Kaushal, R. (2013). Financial effects of health information technology: a systematic review. *American Journal of Managed Care, 19*(10 Spec No), SP369–SP376.

MacLean, C. D., Littenberg, B., & Gagnon, M. (2006). Diabetes decision support: Initial experience with the Vermont diabetes information system. *American Journal of Public Health, 96*(4), 593–595.

MacLean, C. D., Gagnon, M., Callas, P., & Littenberg, B. (2009). The Vermont diabetes information system: A cluster randomized trial of a population-based decision support system. *Journal of General Internal Medicine, 24*(12), 1303–1310.

O'Reilly, D., Holbrook, A., Blackhouse, G., Troyan, S., & Goeree, R. (2012). Cost-effectiveness of a shared computerized decision support system for diabetes linked to electronic medical records. *Journal of American Medical Informatics Association, 19*(3), 341–345.

O'Reilly, D., Tarride, J. E., Goeree, R., Lokker, C., & McKibbon, K. A. (2012). The economics of health information technology in medication management: a systematic review of economic evaluations. *Journal of American Medical Informatics Association, 19*(3), 423–438.

Smith, M. W., & Barnett, P. G. (2008). The role of economics in the QUERI program: QUERI series. *Implementation Science, 3*(20). doi: 10.1186/1748-5908-3-20

Wu, R. C., Laporte, A., & Ungar, W. J. (2007). Cost effectiveness of an electronic medication ordering and administration system in reducing adverse drug events. *Journal of Evaluation in Clinical Practice, 13*(3), 440–448.

Appendix

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Primary Care EMR							
Block (2008) USA	3 years 2005-2007	EMR system vs. paper for net cost and benefit	EMR start-up costs in year-1 with hardware, software, training, implementation, data migration, training, support, lab interface, appointment reminder system in year-2	Reduced staffing cost, increased productivity and billing	Comparison of cost and benefit and net return on investment over 3 years	Year-1 cost saving of $5,500 per month in payroll and benefits, in year-2 increased savings to $6,800 per month; net annual returns of $6,200, $59,250 and $96,150 in years 1, 2 and 3	+ Positive net return on investment; minor ongoing IT costs not included (<$500/physician per year)
Grieger et al. (2007) USA	2.5 years 2003-2005	EMR system vs. paper for net cost and benefit	Year-1 capital cost for hardware, software, technical support, training; ongoing operating expenses	Reduced times for chart pull, new charts, filing, transcriptions; reduced support staff, patient cycle time, days in accounts receivable; improved billing	Comparison of cost and benefit and net return on investment	Year-1 expenses were $509,539, ongoing annual cost year-2 were $114,016; initial costs recovered in 16 months with ongoing savings of $279,524 or $9,983 per provider	+ Positive net return on investment; neutral impact on efficiency and billing
Kumar and Bauer (2011) USA	Hypothetical 5 year time period	EMR system for costs and benefits with no options	Reported software, hardware, installation, training, ongoing maintenance, support staffing, and productivity loss from literature (Wang et al., 2003; Miller et al., 2005); 10% discount rate	Reported savings from transcription, chart pull, malpractice insurance; and chart capture from literature	Simulation with Simulation with random inputs for minimum, maximum and mode cost-benefit estimates; net benefit and present value scenarios at 10%, 15% and 25% discount rates	Net present values of $124,725, $106,635, $79,395 at 10%, 15%, 25% discount over 5 years; worst case scenario with maximum costs, lowest benefits at 25% had (-$9,462)	+ Positive net present value demonstrated across different assumptions, but sensitive to local organizational factors

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Primary Care EMR							
Miller et al. (2005) USA	1 year 2004-2005	EMR system for costs and benefits, with no options	Estimated one time and ongoing EMR, productivity loss, staffing costs from interviews, observations, reports and contracts	Estimated efficiency savings and gains, and revenue enhancement from reports, observations and interviews; averaged per FTE provider	Comparison of cost and benefit per FTE provider, and payback period	Average payback in 2.5 years, $23,000 net benefits per FTE provider per year, some could not recover costs quickly, faced financial risks	+ Need incentives and support services to improve quality of care
Patil et al. (2008) USA	8 years with 4 years each for pre-post periods 1998-2005	Manual vs. EMR system for cost and productivity	Historical costs for manual transcription and EMR implementation and maintenance, with 3% allocation for annual EMR cost, adjusted for inflation in 2006 US dollars	Average net revenue per encounter and per provider over 4 years in pre-post EMR, based on total revenue, transcription cost, EMR cost, encounter volume, and number of providers, adjusted for inflation to 2006 US dollars, extrapolated to 4 years post-EMR with average savings	Comparison of cost/revenue per encounter and per provider, with and without sunk and residual transcribing costs	Average cost saving $3.09 per encounter, increased revenue $117.88 per encounter and $184,627 per provider, start-up EMR cost $10,329 per provider	+ less cost savings if sunk and residual transcribing costs G9
Simon and Simon (2006) USA	1 year not stated, assumed 2005	EMR vs. paper for net benefit/cost	Hardware, software, implementation, training, including discounts and incentives	Tangible cost savings in reduced staffing for managing paper chart, transcription and improved claims	Comparison of costs and benefits, return on investment	Costs of $213,083 and benefits of $657,500, return on investment of 308%	+ Excluded lost productivity from implementation and intangible benefits

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Primary Care EMR							
Wang et al. (2003) USA	5 years not stated, assumed 2002-2006	EMR vs. paper for net benefit/cost	System and induced costs from historical records, experts and literature, discounted at 5% in 2002 US dollars	Estimated cost savings, increased revenues (payer independent, capitation, fee for service), discounted at 5% in 2002 US dollars	Net benefit per provider, with 1, 2 and 5-way sensitivity analysis	Net benefit $86,400 per provider over 5 years	+ based on proportion of patient capitation
Block (2008) USA	3 years 2005-2007	EMR system vs. paper for net cost and benefit	EMR start-up costs in year-1 with hardware, software, training, implementation, data migration, training, support, lab interface, appointment reminder system in year-2	Reduced staffing cost, increased productivity and billing	Comparison of cost and benefit and net return on investment over 3 years	Year-1 cost saving of $5,500 per month in payroll and benefits, in year-2 increased savings to $6,800 per month; net annual returns of $6,200, $59,250 and $96,150 in years 1, 2 and 3	+ Positive net return on investment; minor ongoing IT costs not included (<$500/physician per year)
Grieger et al. (2007) USA	2.5 years 2003-2005	EMR system vs. paper for net cost and benefit	Year-1 capital cost for hardware, software, technical support, training; ongoing operating expenses	Reduced times for chart pull, new charts, filing, transcriptions; reduced support staff, patient cycle time, days in accounts receivable; improved billing	Comparison of cost and benefit and net return on investment	Year-1 expenses were $509,539, ongoing annual cost year-2 were $114,016; initial costs recovered in 16 months with ongoing savings of $279,524 or $9,983 per provider	+ Positive net return on investment; neutral impact on efficiency and billing

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Primary Care EMR							
Kumar and Bauer (2011) USA	Hypothetical 5 year time period	EMR system for costs and benefits with no options	Reported software, hardware, installation, training, ongoing maintenance, support staffing, and productivity loss from literature (Wang et al., 2003; Miller et al., 2005); 10% discount rate	Reported savings from transcription, chart pull, malpractice insurance; and chart capture from literature	Simulation with Simulation with random inputs for minimum, maximum and mode cost-benefit estimates; net benefit and present value scenarios at 10%, 15% and 25% discount rates	Net present values of $124,725, $106,635, $79,395 at 10%, 15%, 25% discount over 5 years; worst case scenario with maximum costs, lowest benefits at 25% had (-$9,462)	+ Positive net present value demonstrated across different assumptions, but sensitive to local organizational factors
Miller et al. (2005) USA	1 year 2004-2005	EMR system for costs and benefits, with no options	Estimated one time and ongoing EMR, productivity loss, staffing costs from interviews, observations, reports and contracts	Estimated efficiency savings and gains, and revenue enhancement from reports, observations and interviews; averaged per FTE provider	Comparison of cost and benefit per FTE provider, and payback period	Average payback in 2.5 years, $23,000 net benefits per FTE provider per year, some could not recover costs quickly, faced financial risks	+ Need incentives and support services to improve quality of care

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Primary Care EMR							
Patil et al. (2008) USA	8 years with 4 years each for pre-post periods 1998-2005	Manual vs. EMR system for cost and productivity	Historical costs for manual transcription and EMR implementation and maintenance, with 3% allocation for annual EMR cost, adjusted for inflation in 2006 US dollars	Average net revenue per encounter and per provider over 4 years in pre-post EMR, based on total revenue, transcription cost, EMR cost, encounter volume, and number of providers, adjusted for inflation to 2006 US dollars, extrapolated to 4 years post-EMR with average savings	Comparison of cost/revenue per encounter and per provider, with and without sunk and residual transcribing costs	Average cost saving $3.09 per encounter, increased revenue $117.88 per encounter and $184,627 per provider, start-up EMR cost $10,329 per provider	+ less cost savings if sunk and residual transcribing costs G9
Simon and Simon (2006) USA	1 year not stated, assumed 2005	EMR vs. paper for net benefit/cost	Hardware, software, implementation, training, including discounts and incentives	Tangible cost savings in reduced staffing for managing paper chart, transcription and improved claims	Comparison of costs and benefits, return on investment	Costs of $213,083 and benefits of $657,500, return on investment of 308%	+ Excluded lost productivity from implementation and intangible benefits
Wang et al. (2003) USA	5 years not stated, assumed 2002-2006	EMR vs. paper for net benefit/cost	System and induced costs from historical records, experts and literature, discounted at 5% in 2002 US dollars	Estimated cost savings, increased revenues (payer independent, capitation, fee for service), discounted at 5% in 2002 US dollars	Net benefit per provider, with 1, 2 and 5-way sensitivity analysis	Net benefit $86,400 per provider over 5 years	+ based on proportion of patient capitation

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Medication Management							
Fretheim et al. (2006) Norway	1-year, assumed 2002	Outreach visit, audit-feedback and computer reminders vs. usual care, cost-benefit	Software and technical support; outreach staffing, training, and travel; cost of drug, physician time, and per patient lab test and	Number, percent and cost of patients being prescribed thiazides vs. other meds, cost in 2002 US dollars with 4% discount on drug cost in year 2	Cost minimization for thiazides vs. others; cost-effectiveness on incremental cost per additional patient started on thiazides	Net annual cost was $53,395, cost per additional patient on thiazides was $454; net annual savings for national program modelled to $761,998	-/+ Intervention cost 2x cost savings in year-1 but could lead to modest savings in 2 years
Wu et al. (2007) Canada	10 years not stated, assumed 2004-2013	CPOE-meds vs. paper for ADE prevention, cost benefit	Historical system and provider workload costs used to estimate annual costs, discounted at 5% in 2004 US dollars	ADE rates estimated from literature and incidence at hospital; number of preventable ADEs	Incremental cost effectiveness ratio, with one-way sensitivity analysis	ICER= $12,700 per ADE averted; 32.3 ADEs averted per year or 261 ADEs over 10 years	+/- based on ADE rate, system and physician cost, and ability to reduce ADEs

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
CPOE/CDSS							
Kaushal et al. (2006) USA	10 years 1993-2002	Single CPOE system for costs and benefits	Internal documents and staff interviews used to estimate capital and operational costs of CPOE, with discount at 7% and annualized values, adjusted for inflation to 2002 US dollars	Benefit data from literature, key informants, internal documents (e.g., operating budget), in savings from reduced ADEs, drug/lab use and improved nursing time use, with discount at 7%, annualized values, adjusted to 2002 US dollars, and 80% prospective reimbursement rate	Net benefit, net cumulative present value, and operating budget benefit from CPOE	Net benefit $16.7M ($2.2M annualized), operating budget benefits $21.3M, net cumulative present value $9.5M ($1.3M annualized), took 5 years to realize net benefit and >7 years to operating budget benefit	+ substantial savings, including operating budget savings over 10 years
Ohsfeldt et al. (2005) USA	5 years not stated, assumed 2001-2005	Statewide CIS-CPOE vs. current CIS for financial impacts	Existing IT infrastructure from survey and estimated CIS/CPOE initial-ongoing costs from vendor, used to simulate CIS/CPOE costs with quadratic interpolation by bed size, and with 5 year depreciation, 5 year borrowing horizon at 5% interest rate	CIS/CPOE cost estimates combined with hospital revenue and cost data for financial impact by hospital type, with 5 year borrowing horizon, 5 year depreciation at 5% interest rate, and through 3rd party payers and reduced errors	Comparison of simulated operating margins for 1st and 2nd year by hospital type, with sensitivity analysis	Operating margins for post-CPOE year-1 and year-2 showed decrease for all hospital types, and deficit for rural and critical access hospitals	+/- CPOE costs may not be financially feasible for small hospitals

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
CPOE/CDSS							
Poley et al. (2007) Netherlands	1 year with 6 months each for pre-post intervention 2001	Pre vs. post CDSS implementation for lab blood test ordering - costs and impacts	Estimated intervention cost (development, installation) for CDSS and staff, lab request cost for staff, material and facility, based on tests per request and volume of requests	Actual lab request costs with volume and tests per request including break-even points	Cost comparison for intervention (CDSS) and lab requests, with t-test, break-even point and sensitivity analysis	Actual cost savings of €847 Euros per practice per 6 months, and break-even point in 5 months	+ no change in lab request volume but did reduce tests per request

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Institutional EHR							
Byrne et al. (2010) USA	7 years 2001-2007, shorter for some components 2003/4-2007	Single system with EHR, PACS, MAR and lab data exchange, compared to not having the tool or component for net value	IT acquisition, operation and maintenance costs estimated in literature, local budgets, contract documents and IT staff, adjusted to 2007 US dollars	Estimated impact from literature, experts, level of adoption and service use in 5 categories: freed space and reduced workload, expense, utilization and redundancy in 2007 US dollars	Modelled net value based on annual and cumulative costs and potential benefits	Potential cumulative benefit $3.09B net investment cost by 7th year	+ spent more on IT than private health care sector but achieved higher IT adoption level and quality of care
Schmitt and Wofford (2002) USA	7 years 2000-2007	EMR with CPOE for radiology, pharmacy and lab; outpatient documentation	Hardware, software, implementation, security devices, imaging, technical support, at 10% discount rate	Staffing time in order processing, manage information/charts, and documentation; revenue from charge capture and claims; ADE rate	Estimated cost benefit and net present value	Projected net benefits of $49,519,094 or net present value of $31,360,953	+ Break-even point in year-2 with net benefits in year-3

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Disease Management							
O'Reilly et al. (2012) Canada	40 year horizon 2010-2049	Intervention vs. control groups compared for treatment effects	Historical immediate (1 year) and long-term (10 years) costs of 7 diabetes complications, and CDSS implementation costs, with 5% discount rates for costs and effects, in 2010 Canadian dollars	Relative risk reduction of complications from year-1 treatment; ICER from net cost of implementing CDSS, cost of treating complications and effectiveness over patient's lifetime	QALYs from year-1 treatment, relative risk reduction in complications, and incremental cost effectiveness ratio, with one-way sensitivity analysis	From year-1 treatment: incremental mean lifetime cost per patient $1,912, 14% relative risk reduction amputation QALY=0.0117, ICER=$156,970 per life year gained, and $160,845 per QALY gained	+ Modest improvement in short-term risk factors and moderate improvement in long-term health outcomes, but costly CDSS intervention

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Immunization Info System							
McKenna et al. (2002) USA	2 years 1998-1999	Immunization information system vs. paper for cost savings	Staff salary, budget and financial reports on development/operating costs for system and staff; observations and interviews for data entry time in year-1, with amortization of investments per child	Projected annual costs for year-2 with development and operating costs, with amortization of total investments and costs per child	Cost comparison for net savings	Actual cost savings in year-1 = $26,768, projected savings in year-2 = $689,403	+ if providers use registries and keep data current

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
Documentation							
Kopach et al. (2005) Canada	4 years 2003-2006	Automated vs. traditional medical documentation for discharge note completion time	Current costs were system maintenance and staff for transcription; estimated automation costs were system, software and staff, cost and note volume discounted at 3%, system depreciated in 4 years, in 2003 Canadian dollars	Historical discharge notes used to calculate mean delay documentation time. Estimated reduction from literature, automation features and historical discharge notes, note volume discounted at 3%, discharge volume increase 1%	Incremental cost-effectiveness ratio, with one-way sensitivity analysis	ICER= $0.331 per day in average discharge note completion time	+/- automation more expensive but cost-effective based on physician utilization volume and length of study

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
HIE							
Walker et al. (2005) USA	10 years not stated, assumed 2003-2012	Three HIE levels: transportable, organizable, interpretable, for net cost/benefit comparison	Interface and provider system costs from acquisition to ongoing maintenance based on literature and experts, in 2003 US dollars; only provider-payer costs were amortized over 3 years	Estimated cost savings from improved lab and imaging testing, prescribing, chart access, referral, provider-payer transactions, public health reporting, in 2003 US dollars	Net benefit, with sensitivity analysis	CBR= $77.8B at level 4, $23.9B at level 3, $21.6B at level 2 by year-11 steady state	+ based on lab and radiology tests

Summary of Economic Evaluation Findings

Study	Time Frame	Options	Cost	Outcome	Comparison	Results	Interpretation
HIE							

Institutional=Institutional Information System; EMR=Primary Care Electronic Medical Record; Documentation=Clinical Documentation System; Disease=Disease Management System; Immunization=Immunization Information System; Medication=Medication Management System; CDSS=Clinical Decision Support System; CPOE=Computerized Provider Order Entry; HIE=Health Information Exchange

ADE: adverse drug event
ADL: activities of daily living
AHA: American Hospital
CBR: cost-benefit ratio
CDR: clinical data repository
CDS: computerized decision support
CIS: clinical information system
DRG: diagnosis-related group
EHR: electronic health record
eMAR: electronic medication administration record
FTE: full-time equivalent
HIMSS: Health Information and Management Systems Society
ICER: incremental cost-effectiveness ratio
IT: information technology
LOS: length of stay
MAR: medication administration record
MDS: minimum data set
N/A: not applicable
PACS: picture archiving and communication system
PCIS: patient care information system
QALY: quality-adjusted life years
US: United States

References cited in Appendix

Block B. (2008). How we improved our practice and our bottom line with a new EMR system. *Family Practice Management, 15*(7), 25–30.

Byrne, C. M., Mercincavage, L. M., Pan, E. C., Vincent, A. G., Johnston, D. S., & Middleton, B. (2010). The value from investments in health information technology at the U.S. Department of Veterans Affairs. *Health Affairs (Millwood), 29*(4), 629–638.

Fretheim, A., Aaserud, M., & Oxman, A. D. (2006). Rational prescribing in primary care (RaPP): economic evaluation of an intervention to improve professional practice. *PLoS Medicine, 3*(6), e216.

Grieger, D. L., Cohen, S. H., & Krusch, D. A. (2007). A pilot study to document the return on investment for implementing an ambulatory electronic health record at an academic medical center. *Journal of the American College of Surgeons, 205*(1), 89–96.

Karnon, J., McIntosh, A., Dean, J., Bath, P., Hutchinson, A., Oakley, J., … Tappenden, P. (2008). Modelling the expected net benefits of interventions to reduce the burden of medication errors. *Journal of Health Services Research and Policy, 13*(2), 85–91.

Kaushal, R., Jha, A. K., Franz, C., Glaser, J., Shetty, K. D., Jaggi, T., … Bates, D. W. (2006). Return on investment for a computerized physician order entry system. *Journal of American Medical Informatics Association, 13*(3), 261–266.

Kopach, R., Geiger, G., & Ungar, W. J. (2005). Cost-effectiveness analysis of medical documentation alternatives. *International Journal of Technology Assessment in Health Care, 21*(1), 126–131.

Kumar, S., & Bauer, K. (2011). The business case for implementing electronic health records in primary care settings in the United States. *Journal of Revenue and Pricing Management, 10*(2), 119–131.

McKenna, V. B., Sager, A., Gunn, J. E., Tormey, P., & Barry, M. A. (2002). Immunization registries: costs and savings. *Public Health Reports, 117*(4), 386–392.

Miller, R. H., West, C., Brown, T. M., Sim, I., & Ganchoff, C. (2005). The value of electronic health records in solo or small group practices. *Health Affairs (Millwood), 24*(5), 1127–1137.

Ohsfeldt, R. L., Ward, M. M., Schneider, J. E., Jaana, M., Miller, T. R., Lei, Y., & Wakefield, D. S. (2005). Implementation of hospital computerized physician order entry systems in a rural state: Feasibility and financial impact. *Journal of American Medical Informatics Association, 12*(1), 20–27.

O'Reilly, D., Holbrook, A., Blackhouse, G., Troyan, S., & Goeree, R. (2012). Cost-effectiveness of a shared computerized decision support system for diabetes linked to electronic medical records. *Journal of American Medical Informatics Association, 19*(3), 341–345.

Patil, M., Puri, L., & Gonzalez, C. M. (2008). Productivity and cost implications of implementing electronic medical records into an ambulatory surgical subspecialty clinic. *Urology, 71*(2), 173–177.

Poley, M. J., Edelenbos, K. I., Mosseveld, M., van Wijk, M. A., de Bakker, D. H., van der Lei, J., & Rutten-van Mölken, M. P. (2007). Cost consequences of implementing an electronic decision support system for ordering laboratory tests in primary care: evidence from a controlled prospective study in the Netherlands. *Clinical Chemistry, 53*(2), 213–219.

Schmitt, K. F., & Wofford, D. A. (2002). Financial analysis projects clear returns from electronic medical records. *Healthcare Financial Management, 56*(1), 52–57.

Simon, S. J., & Simon, S. J. (2006). An examination of the financial feasibility of electronic medical records (EMRS): a case study of tangible and intangible benefits. *International Journal of Electronic Healthcare, 2*(2), 185–200.

Walker, J., Pan, E., Johnston, D., Adler-Milstein, J., Bates, D. W., & Middleton, B. (2005). The value of health care information exchange and interoperability. *Health Affairs (Millwood), Suppl Web Exclusives,* W5-10–W5-18.

Wang, S. J., Middleton, B., Prosser, L. A., Bardon, C. G., Spurr, C. D., Carchidi, P. J., … Bates, D. W. (2003). A cost-benefit analysis of electronic medical records in primary care. *The American Journal of Medicine, 114*, 397–403.

Wu, R. C., Laporte, A., & Ungar, W. J. (2007). Cost effectiveness of an electronic medication ordering and administration system in reducing adverse drug events. *Journal of Evaluation in Clinical Practice, 13*(3), 440–448.