Information Paper

Optimizing adoption and diffusion of medical devices at the system level

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Scope and Objectives

Alberta Health Services (AHS) is seeking new ways to encourage the diffusion of innovative healthcare practices within Alberta. To this end, AHS will establish a guiding framework and toolset for enhancing social-system level diffusion and end-user acceptance of approved healthcare technologies, with the aim of supporting the Strategic Clinical Networks in providing better quality and more efficient healthcare to Albertans.

The Provincial HTA Program at the Institute of Health Economics (IHE) has been asked to describe the current state of evidence on frameworks and methods for health technology adoption and diffusion. Thus, the objectives of this report are to review the published literature on medical device adoption and diffusion at the system level with respect to:

a) models, strategies, tools, and processes for optimizing the adoption and diffusion of health technologies; and

b) factors that affect the adoption and diffusion of health technologies.

The literature review will provide an inventory and broad summary of available models and tools that might inform the creation of an Alberta-specific framework and toolset for medical device adoption and diffusion. An in-depth analysis of, or comparison between, the various models and tools in terms of their comprehensiveness and utility is beyond the scope of this project.

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INTRODUCTION

The combination of an increasing volume of new health technologies and constrained public health budgets has resulted in the need for governments to find ways of optimizing the adoption and diffusion of the most efficient and safe health technologies for their constituents. Only a small fraction of health innovations developed are implemented into practice, which can take years. Promoting the uptake of technologies that provide advances in safety and effectiveness, reduce duplication and cost, and improve outcomes is a priority for decision-makers, particularly given that it is extremely difficult to reverse the utilization of a widely diffused but ineffective technology.[1-3]

Health technologies are complex interventions that are often composed of multiple elements such as technological, organizational, and process innovations. Technology adoption and diffusion affects a variety of stakeholders and is influenced by the nature and complexity of the intervention, the characteristics of the health system and local context, and the perceptions of adopters.[1,4] Adoption is best defined as the discrete decision to accept or reject a health technology.[5] Diffusion is the process by which a health technology is communicated through certain channels among the members of a social system over time.[6] The process of putting the decision to adopt into effect is known as implementation, which although it is often combined in the definition of adoption is actually a distinct process; implementing a plan to adopt a health technology does not necessarily ensure its utilization.[5]

Health technology adoption is a cumulative process that starts slowly and often increases exponentially as the range of adopters expands. During this process, each stakeholder in the health system makes a decision to accept or reject the technology, and every one of these decision nodes represents a point where adoption can be facilitated or hindered. However, the pattern of diffusion also depends on the broader environment in which these stakeholders are situated, including the regulatory and financing system and the culture and structure of the organizations involved.[7] The multiple decision nodes in health care complicate efforts by decision-makers to control adoption and diffusion.[8] This complexity is reflected in the literature on health technology diffusion, which is large and diverse owing to the difficulty of mapping the multiple and often disordered interactions that comprise the adoption process.[9]

Canada is generally a high user of new technologies.[10] In Alberta, the Health Technology Assessment & Innovation Department within Alberta Health Services has three programs, one of which is responsible for identifying new and innovative technologies and promoting their effective and appropriate uptake at the macro and meso level of the health system. A parallel department, the Health Technology Assessment and Adoption Team (HTAA), supports the diffusion and implementation of these innovations through the use of Strategic Clinical Networks (SCNs). These networks are groups of experts with specific clinical expertise who work at the meso level of the health care system to promote uptake of new and innovative ways of delivering care to Albertans.[11-13]

Understanding the factors that shape innovation diffusion would enable decision makers to promote acceptance and increase technology use by generating effective policy initiatives at the system level establishing more decisional systems at the organization level.[8,14] Frameworks are useful tools for analyzing the interactions and interconnections between the multifarious elements involved in the adoption and diffusion of health technologies.[4] Thus, the objective of this report is to provide an inventory and broad summary of available models and tools that might inform the creation of an Alberta-specific framework and toolset for promoting medical device adoption and diffusion.

METHODS

General Approach

An Information Paper is the most appropriate approach for addressing the objectives within the timeframe allotted. Information Papers are reports that focus on methodological or policy issues and are of variable timelines depending on the complexity of the identified issues. The objective was addressed by dividing the topic into three separate, but linked, segments:

1) *Inventory of frameworks and strategies*:
   a) frameworks, models, or strategies for optimizing medical device adoption and diffusion
   b) the effectiveness of frameworks, models, or strategies for optimizing medical device adoption and diffusion
2) *Inventory of tools and processes*:
   a) tools or processes for optimizing medical device adoption and diffusion
   b) the effectiveness of tools or processes for optimizing medical device adoption and diffusion
3) *Inventory of factors that affect adoption and diffusion*:
   a) theoretical factors that may affect the adoption and diffusion of health technologies
   b) validated factors that affect the adoption and diffusion of health technologies

The literature review will provide an inventory and broad summary of available models and tools that might inform the creation of an Alberta-specific framework and toolset for medical device adoption and diffusion. An in-depth analysis of, or comparison between, the various models and tools in terms of their comprehensiveness and utility is beyond the scope of this project.

Inclusion Criteria

Only studies pertaining to medical device diffusion in countries with developed market economies were included, since the health policy environment (for example, regulatory capacity and monitoring systems, ability to influence types and quality of services, and reliance on external donor funds)[15] in countries with transitional or developing economies will likely be too different from that of Canada to be relevant. Countries deemed to have developed economies, as defined by the United Nations, were Australia, Canada, Japan, New Zealand, the United States of America, and European countries (except for those with transition economies).[16]

For the purpose of this report, only articles on the adoption and diffusion of medical devices were included. A medical device was defined as an instrument, apparatus, contrivance, or an in vitro reagent that is used in patients to:

- diagnose, treat, mitigate, or prevent a disease, disorder, or abnormal physical condition, or any of their symptoms;
- restore, modify, or correct the structure or function of any part of the body;
- prevent conception or diagnose pregnancy; or
- care for women or children during pregnancy or at or after birth.[17]

Examples of medical devices include pacemakers, hip implants, synthetic skin, diagnostic or screening instruments, test kits for diagnosis or screening, and contraceptive devices.

Inventory of frameworks and strategies

Articles or studies of any design were included if they contained information on: frameworks, models, or strategies for optimizing medical device adoption and diffusion; or the effectiveness of frameworks, models, or strategies for optimizing medical device adoption and diffusion. For the purpose of this report, the following definitions were adapted from Urquhart et al. 2013[14]:

- Frameworks, which usually draw on multiple theories, comprise a set of factors and describe the relationships between the factors.
- Models depict specific situations and have a narrower scope than frameworks or theories.

Inventory of tools and processes

Articles or studies of any design were included if they contained information on tools or processes for optimizing medical device adoption and diffusion, or on the effectiveness of tools or processes for optimizing medical device adoption and diffusion.

Inventory of factors that affect adoption and diffusion

Articles or studies of any design were included if they contained information on theoretical factors (no analysis of empirical data) that may affect the adoption and diffusion of medical technologies.

Systematic reviews detailing validated factors (analysis based on empirical data) that affect the adoption and diffusion of medical technologies were also included.

Exclusion Criteria

Any study on an intervention that exerts its effects solely by chemical, pharmacological, immunological, or metabolic means was excluded, as were studies on procedures, programs, clinical practice guidelines, health information technologies, and organizational systems.[18]

Medical device adoption and diffusion occurs at multiple levels within the health care system. However, this report focuses only on strategies for promoting the adoption or diffusion of medical technologies at the system or policy (macro) level (Alberta Health and Alberta Health Services). Studies detailing frameworks or processes to facilitate technology adoption at the health care organization or community (meso) level (Alberta Strategic Clinical Networks) or at the patient and health care provider or local (micro) level were excluded.[19]

Given that many studies on system or macro level effects often include elements from the meso level of the health system, these studies were included if the unit of analysis was a health care organization (for example, hospital or hospital consortium) and the framework or strategy considered a whole market or society (macro) perspective. Studies in which there was no consideration of how diffusion at the meso level fits within the larger health care system were excluded.

The following articles were also excluded:

- studies on decision frameworks for prioritizing technologies for diffusion;
- studies on generating or promoting health innovation;
- studies on knowledge and research implementation, adoption, dissemination, or diffusion;

- studies on device implementation;
- studies on non-health care settings;
- studies only available as an abstract; and
- studies referenced within an included systematic review.

Background Information

Where appropriate, additional relevant published information in the form of letters, conference material, commentary, editorials, and abstracts was included as background information.

Literature Search Strategy

A comprehensive literature search was conducted to identify any relevant articles published in English from 1946 to 27 January 2015 (Appendix A). The search was developed and carried out prior to the study selection process. Owing to breadth of the topic area and the difficulty of devising a specific search strategy, the search terms were developed via an iterative process involving the IHE Research Librarian and two reviewers.

Study Selection and Data Extraction

The results of the literature search were collated in a Reference Manager database. Study selection was conducted by two reviewers (DP and AS) on the first 1,000 abstracts listed in the database. The two reviewers compared their selections and discussed the selection criteria. By consensus, articles were excluded if the abstract did not meet inclusion criteria. A single reviewer (DP) screened the remaining abstracts in the database. Owing to the diversity of the abstracts identified and the synonymous use of the terms health technology, health innovation, and medical technology in this field, the inclusion and exclusion criteria were applied conservatively in this initial phase of study selection to ensure that relevant studies were not misclassified.

Copies of the full text of potentially eligible studies were retrieved and examined independently by both reviewers; decisions on final study selection were made by consensus. Excluded papers and reasons for exclusion are listed in Appendix B. Excluded papers were not used to formulate the evidence base for the report, but relevant information contained in these papers was used to inform and expand the review discussion, where appropriate.

Details of the included studies, such as source, key concepts, details of framework application, operationalization of factors, effect on diffusion, and limitations, were extracted by one reviewer using a standard data extraction table and subsequently verified by a second reviewer. Only data on adoption and diffusion that pertained to the relevant level within the health system (that is, macro or blended macro/meso) were extracted; implementation outcomes were not reported.

The methodological quality of the included studies was not assessed.

RESULTS

This report presents a general summary and description of the literature identified. In-depth analysis of the appropriateness and utility of the various models and determinants or factors described is beyond the scope of this project.

The scoping search identified 2,297 citations and the primary search identified 8,628 citations, of which 2,049 were duplicates (Figure 1). After reviewing titles and abstracts, 54 abstracts appeared to be relevant and met the inclusion criteria, while 8,822 citations were excluded for various reasons. Of the 54 full-text articles screened, 9 met the inclusion criteria and 45 were excluded (Appendix B). The grey literature search returned one eligible systematic review.[8] Aligning the included articles to the objectives yielded: four articles relevant for Question 1A,[20-23] one for Question 2A,[1] four for Question 3A,[14,24-27] and one relevant to question 3B.[8] The search failed to return any articles relevant to Questions 1B and 2B.

Research Question 1: Frameworks and Models for Optimizing Adoption and Diffusion

Inventory

No studies were identified that described a framework specific to the adoption and diffusion of a medical technology at the macro level of a healthcare system. However, four relevant models were identified (Appendix C, Table C.1).

Benjamini et al.[20] used game theory to examine the decision process of a single hospital adopting a computed tomography scanner, but the model was not specific to a particular medical technology or healthcare system. The aim was to identify the factors that promote the purchase of more technology to maintain a competitive advantage over other hospitals, and to model the conflict that hospitals face when making choices about technology purchases. The scenarios outlined in the model showed that much of the rapid, uncontrolled diffusion of medical technology is explained by the tension between the hospital sector's best solution and each individual hospital's solution, and between each individual hospital's solution and society's best solution. This dilemma resembles the Prisoner's Dilemma such that: a) when all players act cooperatively, each does better than when all of them act uncooperatively; and b) when there is no binding agreement with the other players for a particular strategy, a player always does better by playing uncooperatively. In this situation, an intervention (for example, by the government) is required, otherwise the players will never arrive at a solution that matches both the needs of individual hospitals and those of the collective hospital sector.

The authors concluded that, without the external intervention of a health planner, the conflict would result in inefficient allocation of resources and loss of welfare to all parties involved. The type of intervention required (for example, central planning, an incentive scheme or regulation) depends on the characteristics of the specific situation as well as the relative strength of the parties involved. When there is an increase in the quality of care through the adoption of a medical technology that affects social benefit, society may be indifferent as to where such change occurs. Therefore, when the best solution for society coincides with the best solution for the hospital sector, the chances of a successful intervention are very high.

FIGURE 1: FLOW DIAGRAM OF STUDY SELECTION PROCESS

Grebel[22] developed a multi-agent model of a German hospital adopting a new technology, percutaneous heart valve implantation, that is manufactured by two different suppliers. The effects of uneven demand preferences, time lag in market entry, and different pricing strategies were modeled on the demand and supply side of the diffusion process. The elements of decision-making on the demand side included the spread of technology through social learning and the tendency of purchasers to favour one manufacturer over another. On the supply side, the following elements were considered: pricing changes over time due to price erosion and company interdependence; changes in supply and demand; changes to the technology that increase its quality; and learning effects resulting from clusters of cardiologists who used the same technology version.

The model showed that, on the demand side, clinicians behave according to preferences that are formed through experience and the influence of champions. The suppliers have to overcome natural preferences through the uptake of technology improvements proposed by users and the use of clinical champions. Firm size and time to market also played an important role in the modeled diffusion process. Late entry into the market led to low market share in the long-term, when price setting strategies weren't able to compensate the time lag. The authors concluded that regulated systems that are aimed at cost containment tend to hinder the introduction of new technologies and may lead to inefficiencies in technology diffusion.

Ramsey and Pauly[23] examined the effects of two types of insurance, managed care and fee-for-service, on technology diffusion in the United States health system by modeling the spread of a new technology alongside the "old" technology. Technology uptake was modeled in two identical consumers at risk for one of two illness severities, moderate or serious, each of which was equally likely to occur. The authors concluded that managed care was neither more efficient nor less inflationary then fee-for-service insurance. Managed care organizations were more likely to adopt a technology that can be limited to a particular patient group (for example, severely ill patients), whereas fee-for-service settings may be prone to technology overuse due to "off-label" application in less ill patients.

George et al.[21] examined the financial effect on manufacturers, health insurers, and society of three post-market regulatory processes in the United States: limited regulation that allows device use outside of clinical trials (current situation); coverage with study participation (CSP) in which the technology can only be used in a clinical trial and the trial costs are reimbursed; and restrictive regulation where use is restricted outside of trials and the clinical trial costs are borne by the manufacturer. Using data from various agencies in the United States, the diffusion of foramen oval closure devices was modeled over a 10-year time horizon. The analysis found that profits for manufacturers were greatest under CSP, which encouraged faster market adoption of effective devices. CSP also provided the greatest societal health benefit and reduced the amount that insurer's paid for ineffective devices, compared with the other regulatory systems. The authors concluded that restricting the out-of-trial use of new devices and extending limited insurance coverage to clinical trial participants potentially balances manufacturer and societal interests and promotes the diffusion of effective devices. It should be noted that this model focussed on a class III, high-risk devices administered in an inpatient setting. Consequently, the results may not be applicable to other medical devices or other clinical settings. Also, the evidence of effectiveness for this device was uncertain, which may have affected the speed of its diffusion.

Evidence of effectiveness

No studies were identified that tested the effectiveness of a framework, model, or strategy for optimizing the adoption and diffusion of a medical technology using empirical data.

Research Question 2: Tools and Processes for Optimizing Adoption and Diffusion

Inventory

No studies were identified that detailed specific tools or processes for optimizing the adoption and diffusion of a medical technology. However, a systematic review by Chaudoir et al.[10] summarised the available tools for measuring factors that affect the implementation and adoption of health innovations (Appendix C, Table C.2). Elements of the tools were coded according to five causal factors (structural, organizational, patient, provider, and innovation-related) that were linked to the implementation outcomes of adoption, fidelity, implementation cost, penetration, and sustainability. Since the focus of this Information Paper was the adoption of medical devices at the macro level of a health system, only data pertaining to tools that exerted an effect on the outcome of adoption at the structural (the broader sociocultural context or community in which a specific organization is situated), organizational (aspects of the organization within which an innovation is being implemented), and innovation-related level (the characteristics of the innovation being adopted) were extracted from Chaudoir et al.[10] A conservative approach was taken such that data were also extracted in cases where a tool may potentially be relevant but the implementation outcome was not stated. However, tools that were implemented in an education, government support organization, workplace, or mental health setting were omitted.

The reviewers searched three electronic literature databases and hand-searched the journal *Implementation Science* to identify relevant English language articles published up to August 2012. Included studies contained at least one measure that was validated or utilized to quantitatively assess a construct that could predict an implementation related outcome in the health field. Study selection and data extraction were conducted independently by two authors, and the inter-rater reliability was assessed (87 to 100%) using a random sample of 25% of the full items. Coding discrepancies were resolved through consensus and consultation with a third reviewer. A total of 62 measures were derived from the 125 included articles.

Fifteen tools were potentially relevant to the objectives of this Information Paper. Nine of the tools were developed by American authors, and two were reported by Canadian authors (the Alberta Context Tool[28] and the Healthy Heart Kit[29]). All of the tools included an organizational level component, and for eight of the tools this was the sole focus. The remaining seven tools measured the effects of multiple factors across the macro, meso, and micro levels of the health system. Only three tools included a structural element, and six tools measured an innovation level component. Of the 15 tools, the following nine were found to be effective predictors of adoption: the Alberta Context Tool; the Attitudes, Perceived Demand, and Perceived Support; the Barriers and Facilitators Assessment Instrument; the Barriers to Research Utilization Scale; the Dimensions of the Learning Organization Questionnaire; the Healthy Heart Kit, Knowledge Transfer and Exchange Correlates; the Organization Readiness to Change Assessment; and the Organizational Culture and Readiness for System-Wide Implementation of Evidence-Based Practice.

The review highlighted the dearth of measures to assess structural level constructs, such as political norms, policies, relative resources and socioeconomic status, and other macro-level determinants. These factors are the least likely to be measured because of the methodological challenges involved. It is simpler for studies to control for structural level factors by stratifying or matching organizations on these characteristics rather than measuring them.

Evidence of effectiveness

No studies were identified that tested the effectiveness of tools or processes for optimizing the adoption and diffusion of a medical technology using empirical data.

Research Question 3: Factors Affecting Adoption and Diffusion

Theoretical factors

Four studies were identified that covered theoretical factors affecting medical device adoption (Appendix C, Table C.3).

Battista[25] discussed the different factors affecting medical device diffusion according to whether the device was high technology (requiring major resource investment), medium technology (products that have intensive development but do not require an elaborate, complex support system), or low technology (require minimal mobilization of resources). Battista stated that producers, user organizations, and governments are the main players in the diffusion process for high technology devices. Competition between producers and between user organizations promotes diffusion. In addition, user organizations are more likely to adopt technologies that are compatible with available equipment and require little resource investment in the form of renovations, space, or staffing. The literature also suggested that user organizations with a teaching affiliation tend to be adopters. Governments have the ability to attenuate or promote adoption and diffusion through legislation, allocation of global budgets, central planning and control of equipment acquisition, grouping of specialized services and health institutions, the assignment of expensive equipment on condition of participation in its evaluation, and modification of operating methods of health organizations.

The adoption and diffusion of medium and low technology are influenced by multiple factors related to providers and patients. For example, trust in the device engendered by knowledge of the technology and the veracity of clinical data can facilitate diffusion among clinicians. Particular provider characteristics, such as their sex, age, and level and type of training, can affect medical technology adoption, as can patient demand. Governments can influence the diffusion of medium and low technology at the meso and micro levels of the health system by creating practice settings that are more conducive to the desired policy objectives. This can be achieved by altering the method of remuneration, the practice environment, or the flow of information on the technology to providers and patients.

Dubois et al.[26] proposed five factors that affect technology diffusion: validity, reliability and maturity of the science; communication of the science; economic drivers; patient and physicians ability to apply the findings; and incorporation into guidelines. Confidence in the device, developed by good communication of trusted data on safety and efficacy, promotes diffusion, as does the ability to apply the device in the local clinical setting. Economic aspects may slow or hasten diffusion depending on the insurer willingness to pay and hospital funding policies. The authors also stated that incorporation into clinical practice guidelines can greatly influence clinician behaviour and accelerate diffusion.

Murtagh and Foerster[27] produced a discussion paper for a Health Technology Strategy Policy Forum held by the Canadian Agency for Drugs and Technology in Health. The paper noted the positive effect that clinician confidence has in the diffusion of a device. The ability to test and observe the device and the formation of links between developers and adopters increased clinician trust. In addition, devices that have greater perceived benefit than existing technology, are compatible with existing techniques and equipment, and can be applied to off-label indications will be adopted more quickly. An extant support structure and the presence of opinion leaders also serve to encourage adoption.

The authors speculated that the diffusion of high-cost technologies can be influenced on the supply side by government regulation, the creation of programs to promote particular health objectives, and controlling access through capital and operating funding. These measures have minimal influence on low-cost technologies. The demand side can be regulated through budget caps (usually used in single payer systems), controlling spending at the service level through coverage and reimbursement decisions (usually used in multi-payer social insurance systems), clinical practice guidelines, incentive funding, performance management, and medical audit.

Urquhart et al.[14] reviewed two conceptual frameworks, the Promoting Action on Research Implementation in Health Services and an organizational framework of innovation implementations with respect to the organizational factors that influence diffusion. The positive influences included management support, availability of financial resources, the degree to which the technology fits with existing values, and the presence of champions.

Validated factors

One systematic review by Varabyova et al.[8] synthesized the evidence on validated factors that influence the adoption and diffusion of medical technologies. The review included published, English language studies of determinants of technological innovation up to August 2014. A comprehensive search of six electronic databases was conducted, in addition to a "snowballing" information collection strategy that included pearling the reference lists of retrieved studies, forward-tracking seminal papers through the Social Sciences Citation Index to identify other relevant articles, and using informal browsing and professional networks. Studies were included if they examined a new treatment or diagnostic technology in the health care setting that required acquisition of capital equipment and analysed adoption and diffusion factors using empirical data; theoretical papers were not included. The factors were coded into four categories: organizational, innovation-related, environmental, and individual. For the purpose of this Information Paper, only data related to the macro or macro/meso level of the health system were extracted (that is, organizational, innovation-related, and environmental factors).

The majority of the 64 included studies were quantitative analyses (78%). Most of the studies were conducted in an inpatient setting in North American, Australia, or Europe, and were focussed on the three medical specialities of radiology, general surgery, and cardiovascular medicine. Sixty individual determinants were catalogued. The most commonly investigated factors were organizational, followed by innovation-related, environmental, and individual.

The authors did not conduct a quality assessment of the included studies, but they stated that most studies were of good quality. However, the following methodological limitations were noted among some of the studies: not being theory-driven; replicating previous research; using small samples; including only a few control variables; not clearly defining innovation; using vague operationalization of innovation determinants; not providing a comprehensive presentation of results; and not conducting sensitivity analyses. Varabyova et al.[8] stated that these shortcomings in the evidence made it challenging to determine to what extent the review's findings were affected by measurement bias or other errors.

Organizational factors

Larger size, group practices, teaching affiliation, greater specialization, research activity, and resource availability were all associated with positive diffusion effects (Appendix C, Table C.4a). Type of ownership had a mixed effect, possibly due to combining the for-profit and non-profit ownership types into the private ownership group. In terms of strategic positioning, hospitals with a technology leadership strategy tend to be early adopters. There was little evidence for the influence of any other strategic factor. When the management of an organization has a favourable attitude to change and an open atmosphere that promotes communication and collaboration, it encourages the transfer of innovation related information and promotes adoption, particularly when there are active linkages between hospitals.

Environmental factors

These factors encompassed health system characteristics as well as the regulatory and market environment (Appendix C, Table C.4b). There was little on the influence of health expenditure, health system organization, or control of investments on adoption. Evidence on the effects of patient co-payment strategies and public or private insurance was equivocal. The only clear outcome for insurance determinants was that managed care had a negative impact on diffusion. In contrast, flexible reimbursement, such as fee-for-service or volume-based remuneration, were more likely to encourage adoption than global budget or salary strategies. This makes sense given that monetary thresholds for equipment will limit technology purchasing capacity.

Hospital and physician competition promote diffusion and the extent of technology use by other organizations has the effect of making non-adopters conform (the so-called bandwagon effect). Urbanized areas tend to have higher levels of adoption than other areas due to greater access to information sources.

Innovation-related factors

There was a consistent, positive association between economic, as well as clinical advantage and innovativeness (Appendix C, Table C.4c). The compatibility of the device with existing setups, and the ability to observe and trial it, also enhance adoption. The availability of information on clinical evidence and supplier promotion materials increased adoption, whereas perceived risk and uncertainty about the device tended to hinder its acceptance. High setup and running costs were also a drawback for device adoption.

LIMITATIONS

The short timeframe for this report necessitated a narrow focus on medical technologies rather than on the broader category of health technologies, which would include interventions such as programs, pharmaceuticals, and health information technology. While this was necessary to ensure that the volume of literature retrieved was manageable, it also severely restricted the pool of relevant articles. Much of the recent literature on adoption and diffusion has focused on administrative and health information technology innovations, particularly in terms of organizational, practice, and service changes.[8] Therefore, potentially useful articles information may have been omitted by restricting the focus of this report to medical technology. However, it is unclear how useful these would be given that medical technologies have distinct characteristics and adoption factors, which would limit the applicability of frameworks constructed for administrative and information technology innovations.[8]

As the literature search was restricted to English language articles, it is possible that some relevant papers from the non-English literature may have been missed. In addition, although a grey literature search was conducted, the reference lists of retrieved articles were not scanned. However, the search terms were broad and aimed for sensitivity rather than specificity, and it is likely that the strategy yielded a relatively comprehensive and representative sample of the relevant literature.

The short timeframe for this report meant some objectives were answered using existing evidence syntheses and reviews. This means that some granularity is lost in grouping and categorizing diverse constructs into a condensed list of determinants and tools. However, the results of these reviews are still useful in that they provide a starting point for delving further into this field of research.

SUMMARY AND NEXT STEPS

No tools or frameworks or tools were identified that were specific to the adoption and diffusion of a medical technology at the macro level of a health care system. Two studies[20,22] modeled technology diffusion at the hospital level and framed their discussion of the outcomes within the broader societal context. Two other studies[21,23] examined the effects of different types of insurance systems and post-market regulatory processes on the adoption of medical technology. Although these provided useful insights, they only modeled singular aspects of the adoption process.

One systematic review[1] identified 62 tools for measuring factors that affect the implementation and adoption of health innovations. Of these, 15 tools were potentially relevant to measuring adoption effects at the macro level of the health system. However, most of the tools were developed by North American authors (two were from Canada), and it was unclear whether these would be applicable in other contexts. The systematic review noted the dearth of measures to assess macro-level determinants of adoption and diffusion.

Four theoretical studies on diffusion determinants were identified.[14,25-27] The majority of the theoretical factors discussed in these papers were corroborated by Varabyova et al., who systematically collated the validated determinants of adoption and diffusion of medical technologies.[8] Thus, many of these determinants are well established.

Much of the recent literature has focused on administrative and health information technology innovations, particularly in terms of organizational, practice, and service changes.[8] An examination of this literature could yield useful strategies and frameworks for promoting adoption and diffusion in Alberta, although it is unclear whether these constructs would be generalizable beyond the field in which they were developed. In addition, recent work on multi-criteria decision analysis[30] may be a useful tool for clarifying the needs, constraints, and values of various stakeholders at the multiple decision points in the adoption process, provided that there has been an adequate synthesis of the evidence pertaining to the medical technology under consideration.

The included papers highlighted the varied and overlapping elements that are characteristic of this area of research. Complementary and competing theories and definitions abound in the field of health technology adoption and diffusion. Most of the models and the studies included in the systematic review of determinants concentrated on a specific technology; few reported on factors or models that could be more universally applied to any medical technology. Given the complex and often messy nature of technology adoption and diffusion, no single framework is likely to definitively capture this complexity. In addition, much of the published work in this area is based on the United States health system, and is not likely to be applicable to the Canadian single payer system. A further consideration is that adoption is a dynamic process. Medical technologies develop as they diffuse and seldom remain static over the course of their lifecycle. As the indications, purpose, or quality of the technology shift, the innovation-related characteristics that affect adoption also change (for example, complexity, compatibility, and trialability).[8] This necessitates a flexible, dynamic framework that can accommodate these contingencies. It may be that the methodologies of health technology assessment also need review to ensure that they are adequate to the task of assessing such "moving targets".

It is likely that a composite framework incorporating items from the research that are relevant to Alberta, the health system level involved, and the particular type of health technology being assessed (for example, medical technology, health information technology, or a program) will provide the nucleus for generating a locally applicable, context-specific framework for promoting adoption and diffusion. An opportunity exists to leverage the existing knowledge and apply it within the unique technology adoption promotion programs that exist within Alberta.

Appendix A: Literature Search Strategy

Search Strategy for Adoption and Diffusion Frameworks

An IHE Research Librarian conducted the literature search on 27 January 2015. Results were limited to English language publications.

TABLE A.1: SEARCH STRATEGY FOR ARTICLES ON TECHNOLOGY ADOPTION AND DIFFUSION FRAMEWORKS

Database/ Date searched	Search terms ††	
MEDLINE (includes in process and other non-indexed citation) OVID Licensed Resource 27 January 2015	1	((technolog* OR innovation* OR intervention* OR device*) adj2 (implement* OR adopt* OR diffus* OR accept* OR integrat*)).tw.
	2	*"diffusion of innovation"/ OR *technology transfer/
	3	*systems integration/
	4	1 OR 2 OR 3
	5	(framework* OR model* OR guid* OR pathway* OR best practice* OR instrument* OR tool* OR plan* OR recommendation* OR process* OR strateg*).ti.
	6	models, theoretical/ or models, organizational/
	7	5 OR 6
	8	4 AND 7
	9	limit 8 to English language
	10	limit 9 to animals
	11	9 NOT 10
EMBASE 27 January 2015	1	((technolog* OR innovation* OR intervention* OR device*) adj2 (implement* OR adopt* OR diffus* OR accept* OR integrat*)).tw.
	2	(framework* OR model* OR guid* OR pathway* OR best practice* OR instrument* OR tool* OR plan* OR recommendation* OR process* OR strateg*).ti.
	3	conceptual framework/
	4	theoretical model/
	5	2 OR 3 OR 4
	6	1 AND 5
	7	limit 6 to English language
	8	limit 7 to animals
	9	7 NOT 8
The Cochrane Library 27 January 2015	1	(technolog* OR innovation* OR intervention* OR device*) near/2 (implement* OR adopt* OR diffus* OR accept* OR integrat*):ti,ab,kw (Word variations have been searched)
	2	MeSH descriptor: [Diffusion of Innovation] explode all trees
	3	MeSH descriptor: [Systems Integration] explode all trees
	4	1 OR 2 OR 3
	5	(framework* OR model* OR guid* OR pathway* OR best practice* OR instrument* OR tool* OR plan* OR recommendation* OR process* OR strateg*):ti (Word variations have been searched)
	6	MeSH descriptor: [Models, Organizational] explode all trees
	7	MeSH descriptor: [Models, Theoretical] explode all trees
	8	5 OR 6 OR 7
	9	4 AND 8

ABI Inform 27 January 2015	(all((technolog* OR innovation* OR intervention* OR device*) NEAR/2 (implement* OR adopt* OR diffus* OR accept* OR integrat*)) AND ti((framework* OR model* OR guid* OR pathway* OR best practice* OR instrument* OR tool* OR plan* OR recommendation* OR process* OR strateg*)) AND PEER(yes)) AND all(health*)

N.B. "*" is a truncation character that retrieves all possible suffix variations of the root word e.g. surg* retrieves surgery, surgical, surgeon, etc.

Search Strategy for Technology Adoption and Diffusion Factors

The IHE Research Librarian conducted the literature search on 27 January 2015. Results were limited to English language publications.

TABLE A.2: SEARCH STRATEGY FOR ARTICLES ON TECHNOLOGY ADOPTION AND DIFFUSION FACTORS

Database/ Date searched		Search terms
MEDLINE (includes in process and other non-indexed citation) OVID Licensed Resource 27 January 2015	1	((technolog* OR innovation* OR intervention* OR device*) adj2 (implement* OR adopt* OR diffus* OR accept* OR integrat*)).tw.
	2	"diffusion of innovation"/ OR technology transfer/
	3	systems integration/
	4	1 OR 2 OR 3
	5	(barrier* OR facilitator* OR determinant* OR enabler* OR obstacle* OR issue* OR driver* OR factor*).ti.
	6	4 AND 5
	7	limit 6 to English language
	8	limit 7 to animals
	9	7 NOT 8
EMBASE 27 January 2015	1	((technolog* OR innovation* OR intervention* OR device*) adj2 (implement* OR adopt* OR diffus* OR accept* OR integrat*)).tw.
	2	(barrier* OR facilitator* OR determinant* OR enabler* OR obstacle* OR issue* OR driver* OR factor*).ti.
	3	1 AND 2
	4	limit 3 to English language
	5	limit 4 to animals
	6	4 NOT 5
The Cochrane Library 27 January 2015	1	(technolog* OR innovation* OR intervention* OR device*) near/2 (implement* OR adopt* OR diffus* OR accept* OR integrat*):ti,ab,kw (Word variations have been searched)
	2	MeSH descriptor: [Diffusion of Innovation] explode all trees
	3	MeSH descriptor: [Systems Integration] this term only
	4	1 OR 2 OR 3
	5	(barrier* OR facilitator* OR determinant* OR enabler* OR obstacle* OR issue* OR driver* OR factor*):ti,ab,kw (Word variations have been searched)
	6	4 AND 5
ABI Inform 27 January 2015		all((technolog* OR innovation* OR intervention* OR device*) NEAR/2 (implement* OR adopt* OR diffuse* OR accept* OR integrate*)) AND all(health) AND ti((barrier* OR facilitator* OR determinant* OR enabler* OR obstacle* OR issue* OR driver* OR factor*))

N.B. "*" is a truncation character that retrieves all possible suffix variations of the root word e.g. surg* retrieves surgery, surgical, surgeon, etc.

Appendix B: Excluded Studies

TABLE B.1: SUMMARY OF EXCLUDED STUDIES

Publication	Reason for exclusion
Atun R, de Jongh T, Secci F, Ohiri K, Adeyi O. Integration of targeted health interventions into health systems: A conceptual framework for analysis. *Health policy and planning* 2010;25(2):104-111.	Not at system level
Bachman TE, Marks NE, Rimensberger PC. Factors effecting adoption of new neonatal and pediatric respiratory technologies. *Intensive Care Medicine* 2008;34(1):174-178.	No mention of diffusion determinants
Barbash G, Friedman B, Glied S, Steiner C. Factors associated with adoption of robotic surgical technology in US hospitals and relationship to radical prostatectomy procedure volume. *Annals of Surgery* 2014;259:1-6.	Included in Varabyova et al. 2014
Barley SR. The alignment of technology and structure through roles and networks. *Administrative Science Quarterly* 1990;35(1):61-103.	No mention of diffusion determinants
Barnett J, Vasileiou K, Djemil F, Brooks L, Young T. Understanding innovators' experiences of barriers and facilitators in implementation and diffusion of healthcare service innovations: a qualitative study. *BMC Health Services* Research 2011;11:342.	No medical device
Bech M, Christiansen T, Dunham K, Lauridsen J, Lyttkens CH, McDonald K, et al. The influence of economic incentives and regulatory factors on the adoption of treatment technologies: a case study of technologies used to treat heart attacks. *Health Economics* 2009;18(10):1114.	Included in Varabyova et al. 2014
Bergman WC, Schulz RA, Davis DS. Factors influencing the genesis of neurosurgical technology. *Neurosurgical Focus* 2009;27(3):E3.	No mention of diffusion determinants
Caudill S, Ford J, Kaserman D. Certificate-of-need regulation and the diffusion of innovations: A random coefficient model. *Journal of Applied Econometrics* 1995;10:73.	Model of a single diffusion factor – not a systematic review
Franchin T, Faggiano F, Plebani M, Muraca M, De Vivo L, Derrico P, et al. Adopting European Network for Health Technology Assessments (EunetHTA) core model for diagnostic technologies for improving the accuracy and appropriateness of blood gas analyzers' assessment. *Clinical Chemistry & Laboratory Medicine* 2014;52(11):1569-1577.	No medical device
Friedman LH, Goes JB, Orr R. The timing of medical technology acquisition: Strategic decision making in turbulent environments / Practitioner application. *Journal of Healthcare Management* 2000;45(5):317-330.	Included in Varabyova et al. 2014
Friedman LH, Myrtle RC. Factors affecting decisions to adopt medical technologies in acute care hospitals. *Journal of Health and Human Services Administration* 1996;18(4):466-489.	Included in Varabyova et al. 2014
Geisler E. Multiple-perspectives model of medical technology. *Health Care Management Review* 1999;24(3):55-63.	No mention of diffusion determinants
Gonzalez L, Aebersold M, Fenske CL. Diffusion of innovation: faculty barriers to adoption. *CIN: Computers, Informatics, Nursing* 2014;32(5):201-204.	No medical device
Gratwohl A, Schwendener A, Baldomero H, Gratwohl M, Apperley J, Niederwieser D, et al. Changes in the use of hematopoietic stem cell transplantation: A model for diffusion of medical technology. *Haematologica* 2010;95(4):637-643.	No medical device
Greenhalgh T, Robert G, Macfarlane F, Bate P, Kyriakidou O. Diffusion of innovations in service organizations: Systematic review and recommendations. *Milbank Quarterly* 2004;82(4):581-629.	No medical device

Publication	Reason for exclusion
Helfrich CD, Tsai TT, Rao SV, Lemon JM, Eugenio EC, Vidovich MI, et al. Perceptions of advantages and barriers to radial-access percutaneous coronary intervention in VA cardiac catheterization laboratories. *Cardiovascular Revascularization Medicine* 2014;15(6-7):329-333.	Provider level – not system level
Hikmet N, Bhattacherjee A, Menachemi N, Kayhan VO, Brooks RG. The role of organizational factors in the adoption of healthcare information technology in Florida hospitals. *Health Care Management Science* 2008;11(1):1-9.	No medical device
Hill SC, Wolfe BL. Testing the HMO competitive strategy: An analysis of its impact on medical care resources. *Journal of Health Economics* 1997;16(3):261-286.	No medical device
James AE, Perry S, Warner SE, Chapman JE, Zaner RM. The diffusion of medical technology: free enterprise and regulatory models in the USA. *Journal of Medical Ethics* 1991;17(3):150-155.	No mention of diffusion determinants
Kimberly JR, Evanisko MJ. Organizational innovation: The influence of individual, organizational, and contextual factors on hospital adoption of technological and administrative innovations. *Academy of Management Journal* 1981;24(4):689.	Included in Varabyova et al. 2014
Kowalczyk N, Stein D. Subjective normative factors impacting technology adoption in an imaging department: Implications for practice. *Radiology management* 2009;31(2):18-24.	No medical device
Lettieri, E. and C. Masella (2009). Priority setting for technology adoption at a hospital level: Relevant issues from the literature. *Health Policy* 2009;90(1): 81-88.	Meso level – not system level
Long G, Mortimer R, Sanzenbacher G. Evolving provider payment models and patient access to innovative medical technology*. Journal of Medical Economics* 2014;17(12):883-893.	No mention of diffusion determinants
May C. A rational model for assessing and evaluating complex interventions in health care *BMC Health Services Research* 2006; 6:86.	No medical device
Mirheydar HS, Parsons JK. Diffusion of robotics into clinical practice in the United States: Process, patient safety, learning curves, and the public health. *World Journal of Urology* 2013;31(3):455-461.	No mention of diffusion determinants
Moore J, Jr. Barriers to technology adoption. *Environmental Science & Technology* 1994;28(4):193A-195A.	No mention of diffusion determinants
Mowatt G, Bower DJ, Brebner JA, Cairns JA, Grant AM, McKee L. When and how to assess fast-changing technologies: A comparative study of medical applications of four generic technologies. SO. *Health Technology Assessment* 1997;1(14):1-149.	No mention of diffusion determinants
Neta G, Glasgow RE, Carpenter CR, Grimshaw JM, Rabin BA, Fernandez ME, et al. A framework for enhancing the value of research for dissemination and implementation. *American Journal of Public Health* 2015;105(1):49-57.	No medical device
Oh E-H, Imanaka Y, Evans E. Determinants of the diffusion of computed tomography and magnetic resonance imaging. *International Journal of Technology Assessment in Health Care* 2005;21(1):73-80.	Included in Varabyova et al. 2014
Olson JR, Belohlav JA, Cook LS. A Rasch model analysis of technology usage in Minnesota hospitals. *International Journal of Medical Informatics* 2012;81(8):527-538.	No medical device
Omachonu VK, Einspruch NG. Innovation in healthcare delivery systems: A conceptual framework. *The Innovation Journal* 2010;15(1): Article 2.	Creation of innovation not diffusion/adoption
Peek ST, Wouters EJ, Hoof J, Luijkx KG, Boeije HR, Vrijhoef HJ. Factors influencing acceptance of technology for aging in place: A systematic review (Provisional abstract). SO. *International Journal of Medical Informatics* 2014;83(4):235-248.	Not at system level
Poulin P, Austen L, Scott CM, Waddell CD, Dixon E, Poulin M, et al. Multi-criteria development and incorporation into decision tools for health technology adoption. *Journal of Health Organization and Management* 2013;27(2):246-265.	Not at system level

Publication	Reason for exclusion
Robert G, MacFarlane F, Peacock R. Organizational factors influencing technology adoption and assimilation in the NHS: A systematic literature review. United Kingdom: (NIH) National Institute for Health Research Service Delivery and Organization Programme; 2009.	Pearled by Varabyova et al. 2014 and relevant studies included in their systematic review
Romeo AA, Wagner JL, Lee RH. Prospective reimbursement and the diffusion of new technologies in hospitals. *Journal of Health Economics* 1984;3(1):1-24.	Included in Varabyova et al. 2014
Sampietro-Colom L, Morilla-Bachs I, Gutierrez-Moreno S, Gallo P. Development and test of a decision support tool for hospital health technology assessment. *International Journal of Technology Assessment in Health Care* 2012;28(4):460-465.	No mention of diffusion determinants
Sillup GP. Forecasting the adoption of new medical technology using the Bass model. *Journal of Health Care Marketing* 1992;12(4):42-51.	No mention of diffusion determinants
Sinclair RC, Maxfield A, Marks EL, Thompson DR, Gershon RR. Prevalence of safer needle devices and factors associated with their adoption: results of a national hospital survey. *Public Health Reports* 2002;117(4):340-349.	No medical device
Sloane EB, Liberatore MJ, Nydick RL, Luo W, Chung QB. Using the analytic hierarchy process as a clinical engineering tool to facilitate an iterative, multidisciplinary, microeconomic health technology assessment. *Computers & Operations Research* 2003;30(10):1447-1465.	No mention of diffusion determinants
Storey J. Factors affecting the adoption of quality assurance technologies in healthcare. *Journal of Health, Organisation and Management* 2013;27(4):498-519.	No mention of diffusion determinants
Straube BM. How changes in the medicare coverage process have facilitated the spread of new technologies. *Health Affairs* 2005;24:W5314-316.	No mention of diffusion determinants
Teplensky JD, Pauly MV, Kimberly JR, Hillman AL, Schwartz JS. Hospital adoption of medical technology: An empirical test of alternative models. *Health Services Research* 1995;30(3):437.	Included in Varabyova et al. 2014
Whitlow J, Shackelford A, Sievert A, Sistino J. Barriers to the acceptance and use of autologous platelet gel. *Perfusion* 2008;23(5):283-289.	No medical device
Whitney B, Teare GF, Gilbart E, Liane SG. The contingencies of organizational learning in long-term care: Factors that affect innovation adoption. *Health Care Management Review* 2005;30(4):282-292.	No medical device
Woo MY, Frank JR, Curtis LA. Point-of-care ultrasonography adoption in Canada: Using diffusion theory and the evaluation tool for ultrasound skills development and education (ETUDE). *Canadian Journal of Emergency Medicine* 2014;16(5):345-351.	Provider level – not system level

Appendix C: Data Extraction Tables

TABLE C.1: SUMMARY OF THEORETICAL MODELS (RESEARCH QUESTION 1A)

Source/ Country	Theoretical foundation and key concepts	Details of application/Assumptions	Policy implications	Benefits/Limitations noted by authors
Benjamini et al. 1986[20] Israel	Based on 2x2 non-zero sum game theory in which the players are two competing hospitals, each of which has two possible options: to buy or not to buy a given technology • Four major groups in a hospital: administrators, doctors, other workers and politicians • Actors in model care about two things: quantity and quality of hospital services • Hospitals look at relative quality of services (i.e. relative to other hospitals or in general) rather than absolute quality	<u>Medical device</u>: Purchase of a computed tomography (CT) scanner, but model can be applied to any technology <u>Context/setting</u>: Any hospital <u>Model Assumptions</u>: • Each player has only two options: to buy or not to buy the technology • The player can only play the game once (in reality it is a repeated game because hospitals are continually faced with adoption decisions) • The game can be applied as one hospital against all others, assuming they are of similar size • The players' decisions are made simultaneously and the players act non-cooperatively • The payoff is the change in quantity or quality of hospital services provided • Presence of the technology increases the quantity and quality of hospital service <u>Application</u>: Tested by substituting dichotomous variables (e.g. 0 if the hospital does not buy a CT scanner and 1 if it does)	Much of the rapid, uncontrolled diffusion of medical technology can be explained by dilemma in which an individual hospital finds itself, resulting from the contrast between individual and collective needs. The interests of society do not appear in the payoff matrix and will differ from those of any individual hospital, and even from the collective interests of the hospital sector. This divergence between social and private goals necessitates outside intervention (of a health planner or payer) to resolve inefficient resource allocation (specific interventions are described for different scenarios). When society's needs coincide with the hospital sector's needs, the government intervention will face less objection than when the converse is true.	None stated

TABLE C.1: SUMMARY OF THEORETICAL MODELS (RESEARCH QUESTION 1A) (CONT'D)

Source/ Country	Theoretical foundation and key concepts	Details of application/Assumptions	Policy implications	Benefits/Limitations noted by authors
George et al. 2014[21] USA	Examined the financial impact on manufacturers, health insurers, and society of the following three post-market regulatory processes for a high-risk, commonly used and approved device: a. limited regulation process: allows device use outside of clinical trials (current USA standard) b. Centers for Medicare & Medicaid Services (CMS) Coverage with Study Participation (CSP) process: restricts out-of-trial use and allows for reimbursement of clinical costs within a high-powered randomized controlled trial c. restrictive regulation process: similar to the US Food and Drug Administration drug approval Process which restricts use outside of trials and places the burden of clinical trial costs on the manufacturer	<u>Medical device</u>: Patent foramen oval closure device for secondary prevention of cryptogenic stroke <u>Context/setting</u>: Federal health planning organizations (USA) <u>Model Assumptions</u>: • Assumed the CSP and restrictive processes would have faster trial enrollment than a limited regulation process due to restriction of competing out-of-trial use (study time frame 3 years versus 6 years) • Ratio of out-of-trial use to in-trial use of 15:1 during limited regulation and 0:1 for other two processes • Time for technology assessment and review after a trial is similar for all three processes • If trials results were negative, assumed utilization would fall to zero; if trial results were positive, assumed a 6% annual incremental increase in market share (estimated probability of effectiveness=69%) <u>Application</u>: Tested using data from the CMS, published literature, the US Bureau of Statistics, medical device company reports, the US Food and Drug Administration, and the Nationwide Inpatient Sample; a series of one-way sensitivity analyses were also applied to model inputs and assumptions	For manufacturers, profits were greatest under CSP, driven by faster market adoption of effective devices, followed by restrictive regulation. Societal health benefit in total quality-adjusted life-years was greatest under CSP. Insurers' expenditures for ineffective devices were greatest with limited regulation. The CSP process maximizes profits for manufacturers and simultaneously reduces insurers' payments for ineffective devices. A process that rewards device value and decreases post-approval trial costs for manufacturers is in the public interest. Regulation restricting out-of-trial device use and extending limited insurance coverage to clinical trial participants may balance manufacturer and societal interests.	<u>Limitations:</u> • Study based on class III/high-risk stroke devices; results may not apply to other device types or to pharmaceuticals • Device effectiveness was uncertain as evidence used was sometimes poor • Model assumed that the device was assessed in a large, randomized controlled trial; alternative methods of assessment may have a different financial impact Model applied to the inpatient setting and may not be applicable to devices with high costs in the outpatient setting

TABLE C.1: SUMMARY OF THEORETICAL MODELS (RESEARCH QUESTION 1A) (CONT'D)

Source/ Country	Theoretical foundation and key concepts	Details of application/Assumptions	Policy implications	Benefits/Limitations noted by authors
Grebel 2010[22] Germany	Examined the diffusion process of two competing innovative technologies Based on an "Arthur-type" model incorporating repetitive adoption with an endogenous individual adoption threshold Focused on the spread of information regarding a new technology within a particular social network driven by professional contacts	Medical device: Percutaneous aortic valve replacement for aortic stenosis Context/setting: Academic hospital (Germany) Model Assumptions: • Unit of analysis was the hospital; assumed that neither patients nor single clinicians were potential technology adopters • Only two suppliers of the technology • Included simple rules for price and quantity • Assumed both technologies equivalent in functionality and quantity Elements of decision making included on the demand side: – social learning – spread of technology – diffusion of competing technologies Elements of decision making included on the supply side: – pricing erosion, interdependency, and reaction to demand surplus – interaction between supply and demand – quality progress of the technologies – individual learning Application: Tested the effects of uneven demand preferences, time lag in market entry, and different price strategies	On the demand side, cardiologists behave according to their own preferences, experience and social networks to determine which technology to adopt on behalf of their patients. Natural preferences can be overcome by the decisions and experience of other clinicians. Firm size and time to market play an important role in diffusion; late entry leads to long-term low market share if price setting strategies are unable to compensate for the time lag. Market structure is determined by the willingness of technology users to adopt a new technology and the influence of network externalities (e.g. improvements in technology proposed by users, influence of clinical champions) on supplier behaviour. In a system where regulation is predominant, the pricing system aims at cost containment rather than at fostering new technologies and leads to inefficiencies.	None stated

TABLE C.1: SUMMARY OF THEORETICAL MODELS (RESEARCH QUESTION 1A) (CONT'D)

Source/ Country	Theoretical foundation and key concepts	Details of application/Assumptions	Policy implications	Benefits/Limitations noted by authors
Ramsey and Pauly 1997[23] USA	Study examines the effects of two types of insurance on technology diffusion: 1) fee-for-service (FFS) insurance, which controls costs on the demand side through cost sharing 2) health maintenance organization (HMO) insurance, which controls cost on the supply side through quantity limits	Medical device: Any Context/setting: Health maintenance organizations (USA) Model Assumptions: Physicians are perfect agents for patients in medical care decisions; physician-induced demand or physician-imposed limits on care cannot occur Insurance companies include a retrospectively paying FFS plan and a prospectively paying HMO which has no copayments There is no off-plan use of the new technology The HMO is able to set restrictions of the amount of treatment offered according to disease severity (optimal managerial limit) Both the "old" and "new" technologies are available for all patients Application: Base-case scenario of a set of identical consumers at risk for one of two illness severities Tested the effect of variations in the technical boundary of treatment relative to the optimal managerial limit	No HMO or FFS health insurer will adopt new technologies that reduce welfare or are ineffective. There should be no a priori policy preference for one type of insurance over another. The rate of technology adoption is not intrinsically higher for HMO or FFS insurance, and neither insurance type is intrinsically more efficient than the other.	None

TABLE C.2: TOOLS FOR MEASURING DIFFUSION OR IMPLEMENTATION RELATED FACTORS IN HEALTH CARE (RESEARCH QUESTION 2A)

Tool	Level of effect	Construct information	Number of studies/ Criterion validity tested
Alberta Context Tool (ACT)	O	Culture, leadership, evaluation, social capital, structural and electronic resources, organizational slack (resources are not completely utilized)	Total Studies: 5 Validity Tested (no. of studies): Adoption* (2); not assessed (3)
Attitudes, Perceived Demand and Perceived Support (ARTAS)	S	Funding and policy support	Total Studies: 1 Validity Tested (no. of studies): Adoption* (1)
	O	Management support	
	I	Adaptability and feasibility	
	PA	Patient benefit	
Barriers and Facilitators Assessment Instrument	S	Societal, political, social context	Total Studies: 2 Validity Tested (no. of studies): Adoption* (1); not assessed (1)
	O	Organizational context	
	I	Innovation characteristics	
	PA	Patient characteristics	
	PR	Provider characteristics	
Barriers to Research Utilization Scale (BARRIERS)	O	Setting barriers and limitations	Total Studies: 13 Validity Tested (no. of studies): Adoption* (3; 2 were statistically significant); not assessed (10)
	I	Quality and presentation of research	
	PR	Research skills, values, and awareness of evidence-based practice	
Competing Values Framework	O	Organizational culture (hierarchal, entrepreneurial, team and rational)	Total Studies: 1 Validity Tested (no. of studies): Not assessed (1)
Context Assessment Index	O	Collaborative practice, evidence-informed practice, respect for persons, practice boundaries, evaluation	Total Studies: 1 Validity Tested (no. of studies): Not assessed (1)
Dimensions of the Learning Organization Questionnaire	O	Continuous learning, inquiry and dialog, collaboration and team learning, systems to capture learning, empower people, connect the organization, provide strategic leadership for learning, financial performance, knowledge performance	Total Studies: 2 Validity Tested (no. of studies): Adoption* (1); not assessed (1)
Facilitators Scale	O	Support for research	Total Studies: 3 Validity Tested (no. of studies): Not assessed (3)
	I	Improving utility of research	
	PR	Education	

TABLE C.2: TOOLS FOR MEASURING DIFFUSION OR IMPLEMENTATION RELATED FACTORS IN HEALTH CARE (RESEARCH QUESTION 2A) (CONT'D)

Tool	Level of effect	Construct information	Number of studies/ Criterion validity tested
Group Cohesion Scale	O	Perceived group attractiveness and cohesiveness	Total Studies: 2 Validity Tested (no. of studies): Not assessed (2)
Healthy Heart Kit	O	Type of practice	Total Studies: 1 Validity Tested (no. of studies): Adoption* (1)
	I	Relative advantage, compatibility, complexity, trialablity, observability	
	PR	Perceived confidence and control	
Knowledge Transfer and Exchange Correlates	S	Policymakers' use of evidence-based practice and funding support	Total Studies: 1 Validity Tested (no. of studies): Adoption (1)
	O	Communication and decision-making	
	PR	Research skill and research activities	
Leader Member Exchange Scale	O	Leadership style, work environment	Total Studies: 2 Validity Tested (no. of studies): Not assessed (2)
Nursing Work Index	O	Hospital characteristics	Total Studies: 3 Validity Tested (no. of studies): Not assessed (3)
Organization Readiness to Change Assessment (ORCA)	O	Culture, leadership, measurement, readiness for change, resources, characteristics, role	Total Studies: 2 Validity Tested (no. of studies): Adoption* (1); not assessed (1)
	I	Evidence: disagreement, evidence, clinical experience	
	PA	Evidence: patient preferences	
Organizational Culture and Readiness for System-Wide Implementation of Evidence-Based Practice (OCRSIEP)	O	Organizational culture, readiness for system wide integration of evidence-based practice	Total Studies: 3 Validity Tested (no. of studies): Adoption* (1); not assessed (2)

*The tool was tested and found to have statistically significant predictive utility for the outcome of adoption; I: innovation; PA: patient; PR: provider; O: organizational; S: structural

N.B. Only tools that appeared to be applicable at the system level and contained at least one of the following levels of effect were tabulated: structural, organizational, or innovation.

Source: [1]

TABLE C.3: THEORETICAL FACTORS AFFECTING MEDICAL DEVICE ADOPTION (RESEARCH QUESTION 3A)

Study details	Variable	Effect on diffusion	Operationalization
Battista 1989[25] Canada Medical device: *High technology*: require major capital investments and mobilization of resources *Medium technology*: products of intensive technological development that can be used without an elaborate and complex support system *Low technology*: does not require mobilization of many financial and human resources Context/setting: Any health system Data Source: Published literature (*cont'd over page*)	**High technology**		
	Producers		
	Competition between companies	+	
	User organizations		
	New technology that is compatible with available equipment/techniques	+	
	New technology that requires little resource investment	+	E.g. requires few major renovations, no additional space, or few highly specialized staff
	Competition between institutions	+	
	Teaching hospital	+	
	Government organizations		
	Legislation mechanisms	Varies	E.g. certificate-of-need, prospective payment linked to diagnosis-related groups, regionalization of services
	Medium/low technology		
	Government organizations		
	Changes in methods of remuneration	Varies	
	Changes in organizational models of practice	Varies	
	User professionals		
	Knowledge about the technology	+	More likely to adopt if professionals know about the technology and it is supported by primary evaluation data
	Trust in the data	+	
	Type of medical training received	+	
	Participation in continuing medical education	+	

TABLE C.3: THEORETICAL FACTORS AFFECTING MEDICAL DEVICE ADOPTION (RESEARCH QUESTION 3A) (CONT'D)

Study details	Variable	Effect on diffusion	Operationalization
Battista 1989[25] (*cont'd*)	Younger physicians	+	
	Female physicians	+/-	Sometimes more circumspect with respect to technology use.
	Specialist training	Varies	E.g. general practitioners are less likely to use technology than specialists.
	Organizational context	Varies	E.g. solo versus group practice, multidisciplinary nature of practice
	Patients		
	Patient demand	+	
Dubois 2013[26] USA <u>Medical device</u>: Any <u>Context/setting</u>: Any health system <u>Data Source</u>: Not applicable	Validity, reliability, and maturity of the science	Varies	Unresolved questions regarding efficacy and benefit can slow adoption
	Communication of the science	+	Dissemination of study results
	Applicability	+	Ability to apply published evidence to specific clinical need
	Economic drivers	Varies	Financial incentives or disincentives: insurers willingness to reimburse and hospital funding influence adoption
	Incorporation into practice guidelines	+	Rapid incorporation into clinical practice guidelines influences clinician behaviour
Murtagh and Foerster 2009[27] Canada <u>Medical device</u>: Any <u>Context/setting</u>: Any health system <u>Data Source</u>: Published literature	Relative advantage conferred by technology	+	The more benefit expected from adopting the technology, the more rapid its diffusion.
	Ability to test the technology	+	Offers the opportunity to reduce uncertainty and risk for adopters.
	Ability to observe the technology in action	+	
	Linkage between developers and adopters	+	For example, through medical journals and conferences.
	Adoption through groups and networks	+	Innovations spread more rapidly among groups with similar characteristics
	Ability of technology to be altered by users	+	For example, application to off-label indications.
	Norms, roles, and social networks	Varies	
	Opinion leaders	+	Opinion leaders reduce uncertainty
	Compatibility of the technology with existing equipment/techniques	+	Ability to integrate with existing technologies.
	Extant supporting infrastructure	+	

TABLE C.3: THEORETICAL FACTORS AFFECTING MEDICAL DEVICE ADOPTION (RESEARCH QUESTION 3A) (CONT'D)

Study details	Variable	Effect on diffusion	Operationalization
Urquhart et al. 2013[14] Canada Medical device: Any Context/setting: Any Data Source: Published literature	Evidence	Varies	
	Context	Varies	Culture, leadership, and evaluation
	Facilitation	+	Providing support to achieve an intended change
	Management support	+	
	Financial resource availability	+	
	Implementation policies and practices	Varies	Organizational policies and practices to support technology use
	Implementation climate	Varies	Employees' perceptions of the extent to which their organization supports the technology
	Innovation-values fit	+	Degree to which the technology fits with existing values
	Champions	+	

+: positive effect; -: negative effect; +/-: equivocal effect; ~: scarce evidence

TABLE C.4A: SUMMARY OF VALIDATED FACTORS AFFECTING TECHNOLOGY DIFFUSION – ORGANIZATIONAL LEVEL (RESEARCH QUESTION 3B)

Determinant	Effect on innovation diffusion	Operationalization	Number of studies (Variables measured)
Type and Structure of Organization			
Larger size	+	Beds, surgical operations, patient visits, discharges, admissions, patient days, births	36 (36)
Group physician practices	+	Group versus solo practice	5 (5)
Teaching status	+	Medical school affiliation, teaching status, number of major residencies	26 (31)
Public ownership	+/-	Public versus private	19 (19)
Centralization	-	Central budgeting authority or decision making	5 (6)
Specialization	+	Proportion of specialty beds or specialists, specialty hospital, innovation-relevant facilities	16 (20)
Functional differentiation	~	Division of hospital into subunits	5 (5)
Case mix index	~	Resource need index, complexity/severity of cases	5 (5)
Technology index	+	Availability of other advanced technology	6 (8)
Research activity	+	Outside research funds, lab or clinical research, publications	7 (12)
Resource availability	+	Availability of uncommitted resources, operating margin, return on sales	17 (19)
Strategic Positioning			
Technology leadership	+	Emphasis on purchasing state-of-the-art products to appear to be a technology leader; domain-offensive behaviour	12 (16)
Patient focus	~	Focus on patient needs regardless of profitability and prestige	4 (4)
Price competitiveness	~	Importance of being price or revenue competitive	3 (3)
Organizational Climate			
Medical involvement	+	Participation in committees for medical matters	7 (9)
Finance involvement	-	Discussion and rigorous financial analysis of proposals	4 (4)
Attitude toward change	+	Physicians/CEOs advocacy of innovation, favourable attitudes toward change	10 (11)
Achievement motivation	~	Concern with improvement and achievement	2 (4)
Consensus	~	Agreement between physicians and administrators	2 (4
Communication	+	Open and friendly atmosphere, dynamic, highly interactive team communication	4 (6)

TABLE C.4A: SUMMARY OF VALIDATED FACTORS AFFECTING TECHNOLOGY DIFFUSION – ORGANIZATIONAL LEVEL (RESEARCH QUESTION 3B) (CONT'D)

Determinant	Effect on innovation diffusion	Operationalization	Number of studies (Variables measured)
Inter-organizational links			
Structural links	+	Chain membership	3 (3)
Non-structural multihospital arrangements	+/-	Involvement in institutional and trade associations, transactions between hospitals	2 (4)
Informational exchange	+	Travel to conferences and courses, paid outside speakers	6 (11)

+: positive effect; -: negative effect; +/-: equivocal effect; ~: scarce evidence

Source: [8]

TABLE C.4B: SUMMARY OF VALIDATED FACTORS AFFECTING TECHNOLOGY DIFFUSION – ENVIRONMENTAL LEVEL (RESEARCH QUESTION 3B)

Determinant	Effect on innovation diffusion	Operationalization	Number of studies (Variables measured)
Healthcare System			
Health expenditure	~	Total health expenditure per capita	2 (2)
Health system organization	~	Vertical integration between insurance and providers	1 (1)
Control over investments	~	Third party rather than hospital control over investments	2 (3)
Type of Insurance			
Patient co-payment	+/-	Out of pocket expenditure, higher percentage of hospital patients as self-payer	5 (5)
Public insurance	+/-	Higher percentage of patients in public insurance	13 (15)
Private insurance	+/-	Higher percentage of patients in private insurance	6 (6)
Managed care	-	Higher percentage of patients in managed care plans	9 (9)
Regulatory Environment			
Provider reimbursement	+	Flexible reimbursement (volume based, diagnosis related groups, fee-for-service) versus global budget, salary	15 (21)
Technology reimbursement	~	Add-on payments, level of reimbursement	4 (5)
Regulation of hospital payments	-	Extent of regulation of payments to the hospitals; anticipation of regulations	9 (9)
Regulation of technology use	-	Higher percentage of certificate of need regulation, difficulties with approval, lack of approval	13 (19)
Competitive Environment			
Hospital competition	+	Hospital density, average number of beds in county, Herfindahl-Hirschman concentration Index, opportunity to choose the provider	26 (37)
Physician competition	+	Higher density of specialists	17 (20)
Bandwagon pressure	+	Use of innovation at other hospitals, distance to substitute technology	15 (15)
Urbanization	+	Higher percentage of urban population, population density, distance to the nearest city; urbanized areas provide greater access to information sources	29 (37)
Income	+/-	Per capita income, household income, income growth, taxable income	19 (21)

+: positive effect; -: negative effect; +/-: equivocal effect; ~: scarce evidence

Source: [8]

TABLE C.4C: SUMMARY OF VALIDATED FACTORS AFFECTING TECHNOLOGY DIFFUSION – INNOVATION-RELATED (RESEARCH QUESTION 3B)

Determinant	Effect on innovation diffusion	Operationalization	Number of studies (Variables measured)
Innovation Attributes			
Relative advantage (economic)	+	Expectations about net revenues, long-term gain and cost effectiveness compared with previous technology	9 (11)
Relative advantage (clinical)	+	Demonstrated clinical effectiveness and efficacy patient welfare	11 (19)
Compatibility	+	Compatibility with other technologies, staff skills, hospital's mission	9 (16)
Complexity	-	Greater time and effort to learn and increased workload with technology	12 (16)
Trialability	+	Try-out equipment, sponsoring of training/ courses	3 (6)
Observability	+	Effect on patient flows, media attention	13 (20)
Information and Costs of Innovation			
Evidence base	+	Availability of clinical evidence and guidelines supporting the technology	10 (13)
Supplier promotion	+	Marketing activities by companies	5 (5)
Uncertainty	-	Concern about early obsolescence, uncertainty about suitable type	7 (10)
Risk	-	Patient injury and malpractice litigation, risk for technicians	6 (7)
Costs	-	High set-up and running costs	10 (15)

+: positive effect; -: negative effect; +/-: equivocal effect; ~: scarce evidence

Source: [8]

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Author Contribution Statements

Dr Ann Scott conducted the study conception, design, literature selection, data extraction, analysis and interpretation, and approved the final version for publication.

Mr Dion Pasichnyk contributed to the study conception, design, literature selection, data extraction, analysis and interpretation, and approved the final version for publication.

Ms Christa Harstall provided critical comment on the design, data extraction, analysis and interpretation, and approved the final version for publication.

Ms Dagmara Chojecki developed and executed the literature search.

This Information Paper is an inventory and broad summary of factors affecting the adoption and diffusion of health technologies and of available models, strategies, tools, and processes for optimizing health technology diffusion.

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