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Identification, Ranking and Prioritization of Decision-Making Criteria for the Early Adoption of Innovative Surgical Technologies into the Canadian Healthcare System: A Multi-Criteria Decision Analysis

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Doctoral Thesis

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ABSTRACT / ABSTRAITE

ENGLISH

Introduction:

In 2020, Canada spent 12.9 percent of its GDP on healthcare, of which three percent were on medical devices. Early adoption of innovative surgical devices is mostly driven by physicians and delaying adoption can deprive patients of important medical treatments. Many surgeons in Canada have different priorities and criteria to base their decisions on adopting a new innovative surgical technology into their practice. However, the lack of evidence-based unified criteria for adoption decisions of technologies in the early adoption stage in Canada affects the quality of healthcare and resource allocation. The aim of this study is to identify and prioritize criteria for priority setting to guide decision-makers for adoption of new surgical technologies.

Methods:

The first study was a scoping review conducted following the PRISMA-ScR reporting guidelines. The search strategy included Canada's provinces, different surgical fields, and adoption. Embase, Medline and provincial databases were searched. Grey literature was also searched. Data were analyzed by reporting the criteria that were used for technology adoption. Finally, a thematic analysis by sub-thematic categorization was conducted to arrange the criteria found. The second study was a Multi-Criteria Decision Analysis using a mixed method methodology through two questionnaires. Questionnaire one was developed

and was sent to 12 experts to validate and identify further criteria/sub-criteria. Questionnaire two was developed and sent to 33 experts to rank the sub-criteria and prioritize the main criteria (domains). Sub-criteria were ranked using the direct ranking elicitation method, (Likert scale) and the domains were prioritized using the composition pairwise-comparison weight elicitation method, the Analytical Hierarchy Process Model. Responses analyzed for the 33 experts and sub-analysis was done for surgeons only and non-surgeons. The consistency of the responses was estimated using the consistency ratio (CR). ANOVA was used to assess for significance of results between the three groups.

Results:

Overall, 155 studies were found. Seven were hospital-specific studies and 148 studies were from four provinces with publicly available websites for technology assessment committees (Alberta, British Columbia, Ontario, and Quebec). Seven domains and 44 sub-criteria were identified. Analysis found that clinical outcomes had the highest priority vector of 0.429, followed by patients and public relevance (0.135). Next was hospital-specific criteria (0.099) followed by technology-specific criteria (0.092) and physician-specific (0.087). The lowest priority vectors were for economic criteria at 0.083 and finally policies and procedures at 0.075. The CR was found to be 0.006 (lower than 0.10) indicating consensus in responses. Statistical analysis with ANOVA compared all participants' responses to surgeons' only and to non-surgeons and found a p-value greater than 0.05 indicating results aren't statistically significant amongst all groups.

Conclusion:

A universal framework for weighted criteria for decision-making in the early adoption stage of novel technologies is lacking in Canada. Ranking of sub-criteria and identifying priority domains paves the way for a systematic approach in decision-making. Putting these criteria into a framework will help surgeons and decision-makers make informed decisions for the adoption strategies.

FRENCH

Introduction:

En 2020, le Canada a consacré 12,9 % de son PIB aux soins de santé, dont 3 % aux dispositifs médicaux. L'adoption précoce de dispositifs chirurgicaux innovants est principalement le fait des médecins et un retard dans l'adoption peut priver les patients de traitements médicaux importants. De nombreux chirurgiens au Canada ont des priorités et des critères différents pour fonder leurs décisions concernant l'adoption d'une nouvelle technologie chirurgicale innovante dans leur pratique. Cependant, l'absence de critères unifiés fondés sur des données probantes pour les décisions d'adoption de technologies au stade précoce au Canada affecte la qualité des soins de santé et l'allocation des ressources. L'objectif de cette étude est d'identifier et de hiérarchiser les critères de définition des priorités afin de guider les décideurs dans l'adoption de nouvelles technologies chirurgicales.

Méthodes:

La première étude était une étude de portée générale réalisée conformément aux lignes directrices PRISMA-ScR en matière d'établissement de rapports. La stratégie de recherche comprenait les provinces canadiennes, les différents domaines chirurgicaux et l'adoption. Les bases de données Embase, Medline et provinciales ont été consultées. La littérature grise a également été recherchée. Les données ont été analysées en rapportant les critères utilisés pour l'adoption de la technologie. Enfin, une analyse thématique par catégorisation sous-thématique a été effectuée pour classer les critères trouvés. La deuxième étude était une analyse décisionnelle multicritère utilisant une méthodologie mixte à l'aide de deux questionnaires. Le premier questionnaire a été élaboré et envoyé à 12 experts pour valider et identifier d'autres critères/sous-critères. Le deuxième questionnaire a été élaboré et envoyé à 33 experts pour classer les sous-critères et hiérarchiser les principaux critères (domaines). Les sous-critères ont été classés à l'aide de la méthode d'élicitation par classement direct (échelle de Likert) et les domaines ont été hiérarchisés à l'aide de la méthode d'élicitation par composition et par comparaison de poids, le modèle du processus de hiérarchie analytique. Les réponses ont été analysées pour les 33 experts et une sous-analyse a été réalisée pour les chirurgiens uniquement et les non-chirurgiens. La cohérence des réponses a été estimée à l'aide du ratio de cohérence (CR). L'ANOVA a été utilisée pour évaluer la signification des résultats entre les trois groupes.

Résultats:

Au total, 155 études ont été trouvées. Sept études portaient sur des hôpitaux spécifiques et 148 études provenaient de quatre provinces où les sites web des comités d'évaluation des technologies sont accessibles au public (Alberta, Colombie-Britannique, Ontario et Québec). Sept domaines et 44 sous-critères ont été identifiés. L'analyse a révélé que les résultats cliniques avaient le vecteur de priorité le plus élevé (0,429), suivi par la pertinence pour les patients et le public (0,135). Viennent ensuite les critères propres à l'hôpital (0,099), puis les critères propres à la technologie (0,092) et aux médecins (0,087). Les vecteurs les moins prioritaires sont les critères économiques (0,083) et les politiques et procédures (0,075). Le CR est de 0,006 (inférieur à 0,10), ce qui indique un consensus dans les réponses. L'analyse statistique avec ANOVA a comparé les réponses de tous les participants aux chirurgiens uniquement et aux non chirurgiens et a trouvé une valeur p supérieure à 0,05 indiquant que les résultats ne sont pas statistiquement significatifs parmi tous les groupes.

Conclusion:

Le Canada ne dispose pas d'un cadre universel de critères pondérés pour la prise de décision au stade de l'adoption précoce de nouvelles technologies. Le classement des sous-critères et l'identification des domaines prioritaires ouvrent la voie à une approche systématique de la prise de décision. L'intégration de ces critères dans un cadre aidera les chirurgiens et les décideurs à prendre des décisions éclairées pour les stratégies d'adoption.

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CONTRIBUTION TO ORIGINAL KNOWLEDGE

Chapter 4, the manuscript that was accepted for publication at the International Journal of Technology Assessment in Health Care, and Chapter 5, that was submitted to the Journal of the American Medical Association – Surgery, include original scholarship that contributes towards knowledge on early adoption of innovative surgical technologies for the Canadian healthcare system. Canada lacks universal criteria that would help guide decision-makers including surgeons to adopt new surgical technologies and no study so far have embarked on such a comprehensive modelling study to define quantitative weights and establish priority-setting for decision-making to guide decision-makers for the early adoption of surgical technologies. The policy implications that were discussed would help guide surgeons and non-surgeon decision-makers to make informed decisions to adopt new innovative surgical technologies into their healthcare settings.

CONTRIBUTION OF AUTHORS

- **Haitham Shoman (H. S.) (PhD student) – (the main author):** Wrote the entire thesis including its chapters. H. S. also conducted all the literature review, data analysis and synthesis for the manuscripts in Chapters 4 and 5. H. S. designed and built the entire MCDA model, wrote the full drafts of chapters, and did the full analysis for criteria weighting, ranking and prioritization and then wrote the manuscripts. All manuscripts were co-authored by the research supervisor (Dr Michael Tanzer).
- **Dr Nisha Almeida (N. A.) – (co-author on the second manuscript "Chapter 5"):** provided manuscript feedback and checked the model for Chapter 5.
- **Dr Michael Tanzer (M. T.) (PhD supervisor) – (co-author on both manuscripts "Chapters 4-5"):** supervised the research, assisted with research questions designs, provided editorial comments and feedback in Chapters 4 and 5. M. T. also provided suggestions for names of experts who can join our research to answer our questionnaires and provided editorial corrections for Chapter 5.

ABBREVIATIONS

AHP	Analytical Hierarchy Process
ANOVA	Analysis of Variance
CADTH	Canadian Agency for Drugs and Technologies in Health
CEA	Cost Effectiveness Analysis
CE	Conformity European
CI	Consistency Index
CR	Consistency Ratio
EU	European Union
FDA	Food and Drugs Administration
GBP	Great British Pounds
GDP	Gross Domestic Product
GPO	Group Purchasing Organizations
HTA	Health Technology Assessment
HQO	Health Quality Ontario
INESSS	Institut national d'excellence en santé et services sociaux
ISPOR	International Society for Pharmacoeconomics and Outcomes Research
LHS	Learning Health System
MCDA	Multi-Criteria-Decision-Analysis
MDD	Medical Devices Directorate
MHRA	Medicines and Healthcare products Regulatory Agency
NHI	National Health Insurance
NICE	National Institute for Health and Care Excellence
OECD	Organisation for Economic Co-operation and Development
OOP	Out Of Pocket
PRISMA-ScR	Preferred Reporting Items for Systematic reviews and Meta-Analyses – Extension for Scoping Reviews
QALY	Quality Adjusted Life Years
RI	Random Index
SSO	Shared Service Organizations
UK	United Kingdom
US	United States

WHO	World Health Organization
WTP	Willingness To Pay
WS	Weighted Sums

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CHAPTER 1: INTRODUCTION

1.1 Rationale:

Canada currently lacks a universal framework for weighted and prioritized criteria for decision-making in the early adoption stage of novel surgical technologies. Some hospitals and provinces have their own internal health technology appraisal committees, but they are not standardized, non-uniform and do not consider a wide array of variables that are crucial to a health system. A lack of a standardized set of criteria that are weighted and prioritized, risks creating a healthcare system that lags behind in providing high-value healthcare services to patients that is timely and accessible. This could also affect surgeons who would miss out on valuable interventions that would enhance operational flow, improve outcomes, enhance patient experience and be early adopters of technologies. Priority setting has always been a challenge for health systems because of the continuous demand for high quality healthcare services and the lack of available resources. With the emergence and rapid diffusion of new innovative surgical technologies, there has been an increasing pressure to contain costs and prioritize criteria to decide on adopting technologies that would ensure the sustainability of the healthcare system.

The adoption of new surgical technologies involves many complex and interrelated factors. The weighting and prioritization of criteria is an essential step in the decision-making process because it simplifies the process by prioritizing the most relevant factors and allows for a more objective decision that aligns with the organization's goals and priorities.

Thus, the aim of this project is to identify, validate, weigh, and prioritize decision-making criteria to guide surgeons and decision makers for the priority setting of the early adoption of new surgical technologies into the Canadian healthcare system.

1.2 Objectives:

1. To identify the criteria currently used by surgeons, hospitals and provincial bodies and characterize the decision-making process for the adoption of new innovative surgical technology in the Canadian healthcare system through a literature review.
2. Identify the current challenges and opportunities in the Canadian healthcare system to adopt new technologies to highlight opportunities in other healthcare systems.
3. To validate the identified criteria and explore additional criteria for the decision-making for the early adoption of new surgical technologies through questionnaires sent to experts in Canada.
4. To establish the relevant weighted and prioritized criteria (domains) that decision makers, including surgeons, HTA experts and surgical administrators can use to make informed decisions for the early adoption of innovative surgical technologies.
5. To establish the relevant ranked sub-criteria that decision makers, including surgeons, HTA experts and surgical administrators can use to make informed decisions for the early adoption of innovative surgical technologies.

CHAPTER 2: LITERATURE REVIEW

2.1 Background

The early adoption of surgical technology has been gaining momentum over the past few decades for several reasons. Studies have identified that being an early adopter of new surgical technology has the advantage of providing high quality healthcare systems and improved patient outcomes (1, 2). Innovative technologies also play a significant role in the modernization of a healthcare system where they can also promote less invasive procedures, reduce patient recovery time, shorten the length of hospital stays, reduce costs, and improve the healthcare system's innovation and sustainability (1). Although surgical technologies are often seen as unaffordable for hospitals functioning with limited budgets, there could be long-term costs savings, improved patient outcomes in the long-run and create health systems that are more efficient and effective (1). There are also studies that showed that being an early adopter of a new surgical technology can sometimes extends from a clinician-centered perspective such as the surgeon's image, the institutional culture to become a center of excellence and increased surgical volume of patients despite the lack of comprehensive evidence on the clinical outcomes of the technology (2, 3). There are studies that show that some decisions to adopt technology were not based on specific unified criteria, but rather on the surgical volume in hospitals driving rapid adoption and technology diffusion (3). It is crucial to study the clinical effectiveness of new technologies and understand whether the rapid adoption was a patient-centered or a clinician-centered decision point (3). Surgical technologies are considered complex interventions composed of a multitude of elements: technological, organizational and process innovations (4). Technology adoption affects several stakeholders and is influenced by the nature of the innovation, health system characteristics, local context, and adopters' perceptions (4). Adoption is defined as *"the discrete decision to accept to reject a health technology" (4)*. The process of technology adoption is cumulative where it usually starts slowly and then gains momentum and grows as the number of adopters increases. The technology adoption curve is composed of five stages: innovators, early adopters, early majority, late majority, and laggards (Figure 1).

The Implantable Cardiac Monitors (ICM) for example was invented in London, Ontario, but it was approved and adopted in the US in 1997, while Health Canada approved it in 1999. Since then, Canada had the lowest utilization rates of 20 implants per one million population compared to the US at 80 implants, Western Europe, and Australia at 50 implants each and the UK at 94 implants per one million. A study explored the late adoption in a hospital between 2002-2011, ICMs led to 12,136 more patients being correctly diagnosed, and $7.1 million annual savings for the Ontario healthcare system. Had ICMs been adopted earlier, more patients would have been diagnosed leading to more savings on the health system (5).

2.2 Technology adoption landscape

The Canada Health Act in 1984, was developed under a fundamental principle of ensuring the well-being of residents without financial barriers through its universal healthcare coverage (6). The system was created to ensure quality care is provided with the best use of resources. Since funds are publicly administered, efficient use of resources is crucial for accountability and effective expenditure of taxpayers' money (7). Integrating new technologies for delivering effective patient outcomes has been considered an indicator of a modernized healthcare system and is considered one of the building blocks of a health system according to the World Health Organization (WHO) (8). Different health system shows different patterns of technological advancements and adoption and in this study, we shed light on Canada's health technology adoption patterns.

Surgical devices and technologies are the most expensive assets of the procurement process, and the purchase is mainly done through regional health authorities or hospitals via global budgets provided by the provincial health ministries (4, 9, 10). Hospitals usually create technology assessment committees acting as the gatekeepers for the adoption of new technologies based on their ability to deliver value (4, 9, 10). These committees' main aim is to improve the care experience, improve health and reduce costs. Understanding the growing role of such committees with set criteria for decision-making, and including surgeons in these committees, will help surgeons make better decisions for technology adoption (4, 9, 10)). Variability in surgeons' preference for certain technologies and a lack of priority criteria for decision-making to adopt new technologies, can lead to a decrease in the quality of care, increased financial costs downstream, and being late technology adopters (4, 9, 10). The lack of unified criteria has led some surgeons to adopt technologies they thought would benefit patients, based on cost and outcomes as recommended from technology appraisal committees and often driven by marketing and sales teams (4, 9, 10).

There has been a fundamental shift over the past few decades from volume-based healthcare towards value-based healthcare by striving for the best health outcomes with the lowest costs and allowing for economies of scale (11). In a movement to create value, Canadian institutions have been responding to this by adopting new technologies into their practice in attempts of being early adopters of technologies. This prompts the use of health technology assessment (HTA) agencies in provinces and the Canadian Agency for Drug and Technologies in Health

(CADTH) to conduct appraisals on new technologies. HTAs are usually conducted based on a systematic review of the clinical effectiveness, a cost effectiveness analysis (CEA) and budget impact assessment. This excludes other important criteria that are crucial to create a value-centered health system and one that is considered an early adopter of innovation.

Organizations in Canada started highlighting the importance of creating high-value healthcare systems via the Learning Health System (LHS) concept which describes a system where "*science, informatics, incentives, and culture are aligned for continuous improvement and innovation, with best practices seamlessly embedded in the delivery process and new knowledge captured as an integral by-product of the delivery experience*" (12). As such, systems would endorse major technological innovations to nurture dynamic approaches to learning and improvement ensuring high quality healthcare to patients (11). With the rising demands for better health services, changes in patient dynamics and needs, aging demographics and shrinking resources, innovation has become the critical factor for the survival of organizations within the healthcare system (13). Healthcare is a product of a wide context of stakeholders, their knowledge, and relationships (13). A study exploring the Organization of Economic Cooperation and Development (OECD) countries' national health innovation systems and innovative output showed that a cluster composed of Scandinavian countries, the Netherlands and Switzerland, had the highest innovations output measured in knowledge production and commercialization (13). Clusters including Canada and the United States (US) came in second (13). However, the cluster including Canada and the US had the highest amount of health patents per population compared to the other OECD countries (13).

Once a surgical technology is granted the regulator license for use in the market, procurement and adoption decisions commence. There are several ways adoption and procurement of technologies occur in Canada. There are group purchasing agreements created by the Share Service Organizations (SSOs) to help leverage buying power, negotiate cost reductions, and facilitate purchasing. These pooled services are usually arranged for by hospital groups (9). Some provinces such as Alberta, British Columbia and New Brunswick have signed contracts with privately owned group purchasing organizations (GPO) (9).

Appraisal for a device is usually conducted after a request from a physician, which then shares the recommendations with the administrators who eventually decide on whether to fund the device for adoption or not (9). By using their criteria, decision-makers can evaluate the potential impact of a new surgical technology, weigh the disadvantages, and make an informed decision that aligns with the organization's goals, needs, and resources. The criteria used to make the decision to adopt innovative surgical technology varies by different governments, HTA, hospitals and surgeons.

2.3 Priority setting for surgical technology adoption

Surgical innovations are usually introduced by individual surgeons under independent circumstances in order to help improve a current technique, implement a new technology or enhance institutional productivity (14). Because of this ad-hoc approach, there is yet to exist a mechanism to capture, analyze and share the lessons learned from these experiences (2, 4, 9, 10). The decision-making processes for the adoption of innovative surgical technologies have not yet been well explored and there is still a lack of a standardized process for the introduction of these innovations into hospitals (14). There has been increasing demand by patients, healthcare institutions and industry for surgical innovations, including the use of minimally invasive devices and procedures (14). This has led to added pressure on surgeons to acquire appropriate skills to help introduce, adopt, and use these technologies and techniques in their practices. With such added pressure from departments and groups, the decision-making process for the adoption becomes more challenging (14). Individual surgeons are not usually fully aware of the internal procurement and adoption administrative procedures to make value judgements about resource allocation. This can result in a decision to adopt a new technology, even though evidence is poor or lacks information on the safety and effectiveness of the innovation (2). It is worth noting that even when evidence exists to support an innovation, it is not always adopted early, such as when the percutaneous transluminal coronary angioplasty (PTCA) became available, it experienced slow adoption rates in some hospitals despite the strong and existing supporting evidence (15).

While scientific basis and evidence on safety and effectiveness is crucial, public accountability is an important consideration when resources are diverted from other causes (16, 17). Due to the scarcity of initial reliable evidence on new innovative surgical technologies, decision-makers in Canadian institutions must balance the value-added benefits against cost and risk to patient safety (4). Hence, a methodology for priority setting is required to help inform guided decision-making for the early adoption of new surgical technologies (18). Because of the challenges behind priority setting and the lack of criteria for technology adoption, decision-makers in hospitals are faced with pressure to set priorities and to provide access to services ensuring they achieve two key goals: legitimacy and fairness (19-21). Legitimacy is defined as "*the moral responsibility to make allocation decisions about available resources"* and fairness is achieved when "*and individual has sufficient reason to accept a priority setting decision because of the acceptability of the decision-making process" (19-21).* Being aware of these goals is important to help shed light on the different adoption patterns that exist and provide guidance to address challenges and obstacles in priority setting in surgery. Surgical innovations still face challenges when compared to other healthcare innovations such as pharmaceutical drugs because of the less governmental regulations on surgical innovations than drugs, budget constraints and the lack of research on practices to adopt surgical innovations. Understanding the factors that shape technology adoption will allow decision-makers to prompt acceptance and increase the use of technology.

2.4 Drivers for the early adoption of new surgical technologies

There have been several motivators that are considered as the drivers for the early adoption of new surgical technology categorized into the below factors.

First, there are also some technological factors that would drive surgeons to adopt these innovations into practice. These include: 1) the technology is adaptable to their current workflow and is supported by existing resources with minimum disruption; 2) surgeons can passively observe the technology being used for the relevant procedure it is intended for; 3) the technology is a simple modification to an existing technology and can be easily and quickly learnt; 4) volume of cases presenting and the anticipated demand justifies the learning and use of the technology (2, 22). A study by BenMessaoud et al showed that there were three main drivers for surgeons who would also tend to be driven to adopt a technology. These are the perceived usefulness, extrinsic motivation, and attitudes towards the technology (22). First, the perceived usefulness of the innovation includes the enhanced functions of the surgical innovation such as: better visualization, higher precision, better dexterity, elimination of hand tremor, better suturing, reliability and better ergonomics (22). Second, the higher extrinsic motivation outcomes such as improved patient outcomes include fewer surgical adverse effects and post-surgical complications which, in turn, led to higher patient referrals and increased job satisfaction (22). Patients tend to be drawn towards market driven trendy technologies that have gained media coverage and wider exposure, which eventually drove surgeons to consider adoption of these new technologies (22). Third, the attitudes towards using the technology played a major role in driving surgeons to adopt a new technology when they realized the new technology is fun to use, the high expectations to further develop the technology, improved portability and is user friendly (22).

Second are the institutional/organizational factors. Several studies have reported that hospitals are motivated to adopt a new surgical technology to improve patient care and attract patients in competitive markets such as in the US (23, 24). Although there might be little evidence regarding improved outcomes of a new technology compared to traditional technologies, hospitals would be inclined to adopt a new technology if the surgery is considered profitable for the hospital (25, 26). For instance, robotic radical prostatectomy faced rapid adoption and diffusion into hospitals to attract patients in areas where competition is high among other hospitals. Thus, this will help attract more surgeons to the hospital, who would then bring in their patients, and hence increase patient volume (23, 24). Patient demand is created for robotic prostate surgery where they would be willing to travel long distances where this surgery is performed. This is based on the consumer driven hypothesis which is created by strong marketing from hospitals and the surgical robot manufacturers (23, 27). Hence, hospitals with more patients having private insurance, and located in places with more surgical specialties, are more likely to adopt robots. If one hospital acquires a robot, other nearby hospitals would also show increased adoption rates, leading to a higher volume of patients (23, 24). Institutions with larger group sizes and practices, teaching affiliations, greater specializations, and more research activities and resources available tend to be amongst the early adopters of new technologies (4). In addition, hospitals with a technology adoption leadership strategy where the management are drawn towards change, endorse an open atmosphere that promotes communication and collaboration, helps encourage the early adoption of new surgical technologies (4).

Third, are individual related factors. Physicians with over 15 years of work experience and those who received their training from manufacturers had a higher tendency to adopt technologies compared to those who got their training only through their residency and/or fellowship (23, 28). In addition, surgeons might be inclined to adopt a new technology because of the image, the institutional culture promoting adoption, or their willingness to take a risk (2).

Fourth are environmental factors that include the regulatory and market environment. Policies that supported flexible reimbursements, such as fee-for-service or volume-based reimbursement, were more likely to support and encourage early adoption of surgical technologies compared to those with budget thresholds which might limit the purchasing capacity (4).

2.5 Barriers for the early adoption of new surgical technologies

Studies showed that lack of exposure, financial cost, long training requirements and concerns with the learning curve hinder the adoption of disruptive new surgical technologies (29). There are some factors that act as barriers to technology adoption. These factors are categorized into seven main categories (30).

First are the technological challenges. This includes the device and innovation characteristics where there are challenges such as: 1) the perceived ease of use and complexity where the use of a new surgical technology has a steep learning curve consuming too much time, effort and the setup of some technologies was cumbersome and time-consuming; 2) perceived usefulness where there is lack of clear benefit using new technologies to replace conventional and traditional ones; and 3) perceived behavioral control where surgeons were used to haptic feedback when feeling organs and applying pressure to organs. But with the introduction of robots, for example, the tactile feedback is lost and some surgeons stated that they would need at least 25 operations to learn to “feel” with their eyes (30, 31).

Second is regulatory affairs. This includes the lack of adequate clinical evidence requirements in the safety and efficacy of the surgical innovations, lack of information on the jurisdictional requirements and the lack of necessary regulatory approvals (29, 30). Although there are surgical innovations that might have a low-moderate risk, they still undergo lengthy submission, trials and approvals process which might hinder the process of early adoption (30, 31).

Third, are challenges with HTA reports and committees. Several reports on new technologies might lack the clinical evidence needed. In addition, the HTA approval submission process can be very lengthy with complex requirements and can lack clarity and transparency on evaluation and timelines. Some HTA committees might lack appropriate expertise or members might lack necessary training in assessing technologies. The committees might also lack key influential experts such as surgeons, who are the primary users of the technologies. HTA reports also tend to look at the budget impact, cost and clinical effectiveness and would lack several fundamental criteria needed to assess new technologies (30, 32, 33).

Fourth, are reimbursement and fiscal compensation barriers. New surgical technologies might come with challenges in the reimbursement process including: 1) the absence and appropriateness of billing and procedural codes which can lead to having these technologies not being used or face delays because of the long and complex nature of the processes for creating and adopting the new codes (30, 34); 2) coverage and payment for these technologies which healthcare providers use to claim payment from third party payers. Limited coverage, or lack thereof, can limit the adoption of the technologies even though they might have clinical recommendations (30, 35); 3) internal policies including the variability of procedures for procurement which can hinder the process of adoption.

Fifth, are individual and demographic carriers. Since surgeons are considered the users of these innovations and champions of a technology, the lack of opinion leaders has contributed to slow adoption behaviors (30). Adoption decisions can also be affected by factors such as age, time since completion of training, type of training and qualifications, academic affiliations, innovativeness and innovation perceptions, workflow disruptions and fear of poor outcomes that can lead to litigation (30, 36, 37).

Sixth, is the lack of clinical evidence. Lack of clinical evidence has been shown to hinder the process of technology adoption. The limitations of validity and quality of evidence compounded with the slow publication times and inefficient communication channels limit the decision-making process to adopt the technology (30, 38). Based on these limitations, there is uncertainty considering the early adoption of technologies.

CHAPTER 3: METHODOLOGY

This original Multi-Criteria Decision Analysis (MCDA) study took place at McGill University and commenced in September 2020. The prioritization and ranking of the criteria were conducted using decision analytic modelling following the guidance of the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) (39, 40). The study was composed of two phases.

3.1. Phase 1

Phase one was a scoping review to identify the currently published criteria in the literature review of how surgeons make decision for the early adoption of surgical technology in the Canadian healthcare system. The study was reported using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses - Scoping Review (PRISMA-ScR) reporting guidance (41). The eligibility of studies was identified using the inclusion and exclusion criteria. Databases were searched for relevant articles and all criteria were extracted into a spreadsheet to facilitate data analysis.

3.2. Phase 2

Phase two included the validation and prioritization of the identified criteria. This was commenced by questionnaire one. Experts were identified by the authors and were contacted to consent to answer our questionnaires. All participants and experts included in this study were selected if they live in Canada and from three main stakeholder groups: surgeons, HTA experts, administrators, and decision-makers in surgical device procurement and actively in practice. They were identified through contacts from the study's senior researcher, researching profiles on websites and emailing different institutions asking for participants who would fit the criteria. All participants were sent invitation letters electronically and given a timeframe of up to four weeks to respond to our questionnaires. Follow-up emails were sent after two weeks. If they participated and completed the questionnaire, that would demonstrate consent. To ensure confidentiality, no names were included and thus, principles of informed consent and confidentiality were met minimizing the risk of harm.

All participants were identified by carefully ensuring their level of expertise is relevant to the subject and on their knowledge of HTA and decision-making in their receptive jobs. Criteria that were included to include experts were: publication in peer-reviewed journals, research topics involvements, contributions to surgical technology adoptions in their respective fields, representation from all provinces, different career levels, different experts' jobs and with no restrictions to gender nor age.

3.2.1. Milestone 1: Questionnaire 1 development

Based on a two-step exploratory methodology, to gain validity and knowledge from experts' opinions and identify further criteria, the first questionnaire survey was developed and distributed to 12 experts (surgeons, HTA experts and administrators) identified by the research senior team. This milestone took place from January until May 2022. The experts examined the 33 criteria that we found from our literature review in phase one, to get feedback on these criteria on whether more criteria/sub-criteria should be added. The questionnaires included tables for each criterion and their relevant sub-criteria in separate tables (Annex 1). Each participant reviewed the list, provided their feedback, and added any further criteria and/or sub-criteria they believed were relevant and not present. Data was collected and responses, including repeated elements, were filtered, coded to obtain a final list for our study and finally, new criteria categories (domains) and sub-criteria were identified. All newly identified sub-criteria were condensed based on similarity with existing sub-criteria creating a more manageable number of items and added to the discrete thematic groupings, or main criteria, produced a priori.

3.2.2. Milestone 2: Questionnaire 2 development

After reaching out to 45 experts, 33 responded with a response rate of around 73%. All participants were selected from different provinces, having surgeons, HTA experts and administrators. This milestone took place from June 2022 until November 2022. They were all sent the second questionnaire with two main objectives: first to rank the sub-criteria using the Likert scale on a scale of 1-5 (one being irrelevant and 5 being absolute relevance). The second objective was to determine which criteria are more important than the others. Here experts were asked to evaluate the various criteria by comparing two criteria at a time, a technique known as pairwise-comparison (42). Saaty's scale (1-9) was used where 1 determined equal importance and 9 was absolute importance for the entire range of the 7 criteria (42, 43) (Annex 2).

3.2.3. Milestone 3 – Sub-criteria data analysis

The sub-criteria were ranked based on the direct rating Likert scale to elicit priority rankings. Each sub-criterion was considered independently, and its importance was on a scale of 1-5. The responses from the experts were then analyzed using the arithmetic mean. The sub-criteria were then re-arranged based on their rankings from most important to the least important.

3.2.4. Milestone 4 – Criteria categories (domains) data analysis and model development

The first step was to define a clear problem statement at the beginning of the Analytical Hierarchy Process (AHP) model along with the domains and alternatives for decision making (40, 44) . This structured decision-making framework is used when there are complex comparisons that need a decision on their priorities. Figure 2 shows the AHP framework outline. The defined problem was the lack of unified and standard criteria for the decision-making for the early adoption of new surgical technologies in the Canadian healthcare system.

The second step was the development of the hierarchical model. The AHP classifies the main goal, all decision domains, and sub-criteria into different levels. Level 1 is the goal, and it is the highest level of the hierarchy (Chapter 5 – Figure 3) which is the adoption of surgical technologies. Level 2 represents the domains and level 3 represents the sub-criteria.

The third step is constructing the pairwise comparison matrix using the Saaty's 9-point scale (Table 1). Questionnaire 2 incorporated the questions that were given to experts where they compared two domains against each other. We made sure that the experts were very familiar with the adoption of surgical technologies in their healthcare settings and had sufficient knowledge to answer the questions.

The fourth step is data synthetization. Data were analyzed using a mixed model methodology (Likert scale and pairwise comparisons). Microsoft Excel Office 365 package was used to build the entire model. The domains were prioritized using the compositional pairwise comparison matrix by adopting the AHP model. The AHP is efficient in addressing complex decision-making, helping teams establish priorities and choose the best option (42, 43). The AHP calibrates the subjective and objective aspects of a decision through its five steps: a) hierarchical structure development, b) pairwise-comparison, c) criteria-weights calculation, d) computation of option scores matrix, e) ranking of the criteria (42, 43). Here alternatives are compared pairwise on each criterion and their "intensity of importance" relative to each other is expressed on a ratio 1-9 scale. The AHP helps address the survey fatigue phenomenon by asking experts to only compare the importance of two domains at a time (42, 43). Judgements of only two domains at a time is easier for experts than comparing more than two domains at a time (42, 43). The judgements, by experts, applied in making the paired comparisons combine logical thinking with intuitive feelings that were developed from the experience (42, 43). Pairwise comparisons help generate more information which, in turn, leads to improved judgement consistency (43). The geometric-mean approach was then used to combine the individual pairwise-comparison judgments of the 33 experts into the pairwise-comparison matrix from the generated 7x7 tables. This was followed by estimating the normalized matrix scores for eliciting the criteria weights (W) and then computing the weighted sums (WS).

The fifth step is to verify the consistency of the comparisons. The consistency index (CI) was applied for the entire pairwise-comparison matrix (42, 43). Lambda was then calculated by dividing WS by W and eventually Lambda Max (λmax) which is the arithmetic average of all Lambdas from the 7 criteria. The "λmax" is the Maximum Eigenvalue of the matrix of the importance ratios and “n” is the number of factors (42, 43). The consistency ratio (CR) was then used to determine whether the matrix was sufficiently consistent or not. The random index (RI) was then selected based on the number of categories (n=7 and RI=1.32) (42, 43) (Table 2). The RI is the CI of a matrix of comparisons and the CR is the ratio of the CI to the RI. A CR of <0.1 indicates that the results of the pairwise comparisons are consistent.

$$CI = \frac{((\lambda\, Max) - n\,)}{(n-1)}$$

$$CR = \frac{CI}{RI}$$

The sixth step, after completing the 7x7 table pairwise-comparisons and based on the experts’ judgments, the AHP was applied to determine the weights of the relative importance for each domain, the priority vector. Tables 3-7 show the full model calculations and results.

3.2.5. Milestone 5 - Statistical analysis

Statistical analysis was performed to assess the statistical significance between the findings of the priority vectors in the seven criteria in the three groups of results from surgeons only, non-surgeons and all participants. Then the statistical significance between the priority rank findings of the 44 sub-criteria of the same three groups (surgeons, non-surgeons, and all experts) was conducted. The null hypothesis states that there are no statistical differences in the results from the three groups. The analysis was conducted using a one-way analysis of variance (ANOVA) in Microsoft Excel – Office 365 package. Table 8-9 shows the outputs of the ANOVA results.

BODY OF THE THESIS

CHAPTER 4: MANUSCRIPT 1

Provisionally accepted for publication at the International Journal of Technology Assessment in Health Care

Full title: DECISION-MAKING FOR EARLY SURGICAL TECHNOLOGY ADOPTION INTO CANADA'S HEALTHCARE SYSTEM: A SCOPING REVIEW OF THE DECISION-MAKING CRITERIA, CHALLENGES AND OPPORTUNITIES

Running title: Decision-making for new surgical technology adoption

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ABSTRACT:

Introduction

In 2020, Canada spent 12.9 percent of its GDP on healthcare, of which 3 percent was on medical devices. Early adoption of innovative surgical devices is mostly driven by physicians and delaying adoption can deprive patients of important medical treatments. This study aims to identify the criteria in Canada used to decide on the adoption of a surgical device and identify challenges and opportunities.

Methods

This scoping review was guided by the Joanna Briggs Institute Manual for Evidence Synthesis and PRISMA-ScR reporting guidelines. The search strategy included Canada's provinces, different surgical fields, and adoption. Embase, Medline and provincial databases were searched. Grey literature was also searched. Data were analyzed by reporting the criteria that were used for technology adoption. Finally, a thematic analysis by sub-thematic categorization was conducted to arrange the criteria found.

Results

Overall, 155 studies were found. Seven were hospital-specific studies and 148 studies were from four provinces with publicly available websites for technology assessment committees (Alberta, British Columbia, Ontario, and Quebec). Seven main themes of criteria were identified: economic, hospital-specific, technology-specific, patients/public, clinical outcomes, policies and procedures and physician specific. However, standardization and

specific weighted criteria for decision-making in the early adoption stage of novel technologies are lacking in Canada.

Conclusion

Specific criteria for decision making in the early adoption stage of novel surgical technologies are lacking. These criteria need to be identified, standardized, and applied in order to provide innovative, and the most effective healthcare to Canadians.

Keywords: decision, adoption, surgical technology, healthcare system, Canada

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INTRODUCTION

Countries have developed healthcare systems in order to ensure people have access to healthcare in a coordinated fashion and ensure the wellness of their nations. The World Health Organization (WHO) considers health systems as all the organizations, people and actions that have a primary intent to promote, restore or maintain health including efforts to affect the determinants of health and more directed health-improving tasks (1). Healthcare systems are defined by three main dimensions financing, service provision and regulation (2). There are four main types of healthcare systems: the Bismarck model, the Beveridge model, the National Health Insurance (NHI) and the Out-of-pocket (OOP) model (2,3). Canada primarily uses the NHI model where the healthcare system is funded directly by income tax deductions and the facilities are owned and operated by the government (2-4). The Canada Health Act, 1984, was developed to ensure eligible residents have universal access to healthcare services (4). Delivery of services is determined by provinces and territories that pool funds into general revenue and the federal government contributes to the revenue pools as per the Health Transfer Agreement (4). Private health insurance can be purchased through employers to cover medical services not covered by the Act (4).

It was estimated that Canada spent approximately CA$ 305 billion on healthcare in 2020, representing 12.9 percent of GDP with an average of CA$ 7,507 per capita. This is above the Organization for Economic Co-operation and Development (OECD) average of CA$ 5,502 per capita (5). The amount spent on medical devices and technologies in Canada is 3-5 percent of the healthcare expenditure, although these estimates are not systematically tracked (4). OECD developed countries are always looking to improve their healthcare systems and are considered early adopters of new technologies that benefit patients.

Surgery is a highly technical specialty that commonly uses advanced devices and technologies to treat patients. The purchase and adoption of these technologies can occur at any time in the technology adoption life cycle from the innovators to the early adopters, to the early majority, to the late majority, and finally to the laggards (6). The initial decision to adopt surgical technology is by the surgeon, who is the primary user of the device. In the early adoption stage and where there is lack of well-established criteria for decision-making, surgeons can decide to adopt technologies based on factors such as: a) surgeon's preference, b) beliefs about the benefit of the technology for their patients, c) presentations from conferences, and d) information from marketing and sales teams (7).

Innovation take-up is a dynamic process involving multiple formal/informal decisions by a multitude of interactive factors. In Canada, technology purchase is mainly done through regional health authorities or hospitals via global budgets provided by the provincial health ministries (4). Some provinces tend to use health technology assessments (HTA) for devices or drugs, but it is unclear at which stage this assessment is conducted. Surgical devices and technologies are one of the most expensive expenditures of the procurement process. Hospitals commonly create technology assessment committees that act as the gatekeepers for the adoption of these new technologies by assessing their value-added benefit (7). However, in the early adoption stage, clinical outcomes of the technology are limited and of short duration, making the assessment of value difficult, if not impossible. Since there is limited information on clinical outcomes on surgical technologies at the early adoption stage, which is considered within the exploration stage (stage 2b) of the IDEAL framework, informed criteria for decision-making, mentoring and learning curve evaluation would be considered important (8).

Understanding the role of provincial and local technology assessment committees and the criteria for decision-making will help surgeons better recognize the opportunities and requirements to influence the early adoption of innovative technology for the surgical care of their patients (7). The aim of this study is to identify the criteria used by surgeons, hospitals and provincial bodies and characterize the decision-making process for the adoption of new innovative surgical technology in the Canadian healthcare system. The study will also explore the current challenges and opportunities in the Canadian healthcare system to adopt new technologies to highlight opportunities in other healthcare systems.

METHODS

The methodology for the study was conducted following the Joanna Briggs Institute (JBI) Manual for Evidence Synthesis (9). This study was also reported using the Preferred Reporting Items for Systematic Reviews and Meta-analysis for Scoping Reviews statement guidelines and flowchart (PRISMA-ScR) (10).

Search strategy

A literature review was conducted using MEDLINE and EMBASE databases; and Google Scholar searching for grey literature. A medical librarian has been consulted for assistance with the keywords and literature search. Provincial health technology assessment (HTA) websites in Canada were also searched along with federal HTA agencies including the Canadian Agency for Drugs and Technologies in Health (CADTH). Search terms were developed to identify articles for the study, and they included the 10 provinces and 3 territories in Canada, all surgical fields, decision-making, opportunities, challenges, adoption, innovators, and health technologies. Medical subject headings (MeSH terms) used were "surgical procedure", "decision-making", "surgical technologies", "Canada". All terms were combined using Boolean terms "And" / "Or". The search terms used are found in Table 1.

Study selection (inclusion and exclusion criteria)

The study selection and screening were conducted by two independent reviewers and there were no disagreements. This review only included articles published from inception until December 2021. Articles included were observational studies, randomized trials, HTA's, case studies and series. The study included articles focused on the decision-making process for early new surgical technology adoption into clinical practice, articles published in English and

French, articles that focus only on the Canadian healthcare system and its 13 provinces and territories and articles that explore the strengths and weaknesses in the Canadian system for technology adoption. The articles that focused on the decision-making process include whether these were decisions already made to adopt a technology, or decisions yet to be made by physicians. All hospital-based and province-based studies were considered and screened for eligibility according to the inclusion criteria and were then referred for full-text assessment. Articles outside Canada, in languages other than English and French which did not include adoption of technologies were excluded from this study.

Data extraction

Articles found were imported into Endnote X9 reference manager software where duplicates were removed and the filtration process for all studies took place. There were no disagreements between authors. The data was then extracted into a spreadsheet created in Microsoft Excel (Table 2). The data extracted included information based on the author and year the article was published, the level of evidence and study type, the geographic location, surgical specialty, the surgical device (technology), decision-making framework and criteria, challenges, opportunities, and general applicability. Data was also extracted from provincial websites identifying the criteria used and responsible HTA agency (Table 3).

Data synthesis and analysis

Articles found were grouped into hospital-based and province-based studies. Criteria that were used by physicians in the decision-making process for technology adoption were collected and reported. The frequency of reporting of each criterion was also collected. The criteria were then grouped and classified based on a thematic categorization of all the criteria and guidance sought from previous studies (11, 12). Finally, the surgical technologies identified in the studies were grouped into surgical fields along with when they were adopted.

RESULTS

The search strategy for this study yielded a total of 4,966 articles (4,195 from the database search and were hospital-based; and 771 from provincial websites). After duplicates were removed and screening was done, the searches identified 155 articles that met the inclusion criteria (Figure 1). Of these, 148 were HTA reports from provincial websites, four were case studies and three were policy review articles. A total of ninety-three articles were from Ontario, forty were from Quebec, thirteen were from Alberta, seven were from British Columbia, one was from Nova Scotia, and one was a national study. The technology assessed included surgical devices for cardiothoracic surgery, general surgery, obstetrics and gynecology, orthopedics, and ophthalmology. None of the articles indicated in which stage of the technology adoption life cycle the technology was in at the time of its review. Figure 2 shows all criteria and sub-criteria found from the search strategy.

Criteria elicitation – HTA reports from provinces

All 148 provincial HTA reports used the same methodology which included a systematic review, an economic evaluation, and a budget impact analysis of the technology. Provinces used a set of criteria that were determined by each province and were only standardized across the HTA reports that they used (13). Table 3 shows a summary of the information gathered from the provincial websites. The price of the technology and its clinical effectiveness (safety and effectiveness) were the most important criteria used in the decision-making process in all the provinces (2-6). In three provinces, political and public policy considerations, as well as social and system demographics (incidence and prevalence of the condition) were used to guide their decisions and they were considered additional criteria (13-17). The political and public policy considerations include access to the technology, environmental impact, prevention of diseases, risk of implementing the technology, and impact on marginalized/disadvantaged patients. One of the provinces also used societal and ethical values in considering which technologies to adopt along with the feasibility of adoption into the healthcare system (13-17). Cost, safety, efficacy, economic impact and feasibility of implementation of the technology were the most frequently reported criteria across all studies. This is in line with the provincial priorities on what guides them to adopt new technologies into their hospitals.

Thematic groupings and criteria elicitation (from the seven articles)

Seven articles from the database search identified the priority criteria that surgeons use in their decision-making process to adopt a new surgical device (18-24). All the criteria were gathered systematically by the authors using structured methodologies from the JBI Manual for Evidence Synthesis (9). Overall, thirty-three criteria were identified as influencing surgeons, and other healthcare professionals, in adopting a new technology. The criteria were extracted from Table 2. The methodologies used include using different qualitative frameworks with questionnaires designed to ask surgeons what is considered important in their decision-making process. These frameworks are the Alberta Heritage Foundation for Medical Research Framework, the Accountability for Reasonableness, the Socio-technical dimensions and features, the Calgary Health Region HTA and the Organizational Framework of Innovation Implementation.

The 33 criteria had recurrent themes and could be categorized by thematic categorization into seven distinct groups of criteria (Table 4). Group 1 includes all the criteria that relate to the economics of the technology. Group 2 includes the hospital-specific criteria and refers to how this device fits into the hospital's ecosystem, integration, and workflow. Group 3 includes the technology-specific criteria and refers to features that define the device and its specifications. Group 4 is the relevance to patients and the public and these criteria refer to the usability of the technology/device to the overall population and their feedback. The Group 5 criteria are related to clinical outcomes from the clinician's perspective. Group 6 is policies and procedures criteria and refers to regulations in the country/hospital that facilitate integration and ease of usability of the technology. Finally, group 7 are criteria that are physician-specific and refers to how the physician interacts with the technology. It is worth noting that there was no weighting of any of the thirty-three criteria in considering which is more important among the studies.

Challenges

Three of the studies identified challenges with the criteria used by surgeons to adopt novel technology. First, there is expressed uncertainty about whether or not these criteria were generalizable for all technologies in all surgical specialties (20). Second, there was potential bias in the surgeon's criteria, thereby limiting its applicability since these criteria were prioritized by physicians in large hospitals and may not be generalizable nor applicable to smaller hospitals with smaller budgets and limited access (19). Third, Canada's healthcare system presently lacks a universal strategic system with a guide on how to adopt new technologies (21). Furthermore, provincial HTAs only assess technology based on cost-effectiveness, budget impact and clinical outcomes.” Two of the studies found that there might be a recall bias where some physicians could not recall the last time, they decided on how or why should a new technology be adopted (23, 24).

Opportunities

All seven studies, including the two studies that utilized provincial HTA criteria, identified specific opportunities that could help improve the Canadian healthcare system in procuring new technologies at the early adoption stage. These opportunities addressed the process at both the provincial and hospital level. First, surgeons with well-defined criteria to adopt a new technology would help in providing a useful evidence-based framework for decision-making. This primary data collection is considered a supplement to the evidence available for formal HTA reports (20). Second, criteria gathered from surgeons would help enhance the strength and availability of evidence while enabling decision-making to balance what is needed for policy formulation (18). Third, such criteria collected would help in triggering hospitals to better develop a structure that would involve wider stakeholders for more input and prompt the development of a comprehensive appeals mechanism for addressing challenges to decisions made (19). Fourth, such criteria would help manufacturers create websites for these products that would bolster the surgeons’ expectations and needs by answering their questions based on the criteria already gathered a priori (21). This would help create a more transparent platform for surgeons to make more informed decisions. Fifth, HTA programs available locally and nationally help bridge gaps where evidence is lacking to support surgeons' knowledge of a new technology for more informed decisions (22). Sixth, public representation along with physician's expertise to ensure public and patient insights are taken into consideration (23). Finally, the adoption of technologies should involve internal multi-level stakeholders' such as administrators, other health professionals and hospital decision makers early in the process to facilitate uptake and adoption since there are regulations that can either prompt or hinder adoption apart from surgeons' needs (24).

Applicability

The views on the applicability of using these criteria amongst all provinces and hospitals differed between authors. In two studies, it was contended that the observations in one hospital and community might not be generalizable because of the diverse structure and socio-political context of healthcare systems in different jurisdictions (23, 24). In addition, this is further confounded by a wide range and diversity of stakeholders, complex governance structures, resource arrangements and high degrees of professional autonomies (24). Two of the studies felt that the inclusion of the surgeons in the decision-making process made the adoption assessment more applicable and universal. Goeree et al 2009 speculated that when physicians' criteria for adoption are supplemented by HTA reports outcomes, it could help create more informed decisions that would be applicable to different settings (20). In addition, applicability to other systems and feasibility of such criteria could be possible when decisions include several stakeholders, especially from the government, so that there is a balance from a multitude of factors including the regulatory environment (18).

DISCUSSION

The aim of this study was to identify the criteria used to determine the decision-making for new technology adoption. Thirty-three criteria were identified and grouped into seven categories named: economic, hospital-specific, technology-specific, patient-specific, clinical outcomes, policies, and procedures and finally physician-specific. In the Canadian healthcare system, there is no standardization of decision-making criteria in technology adoption. Although there is some overlap between the criteria felt to be important by surgeons and the provincial/hospital committees, the provincial and hospital committees focus primarily on the cost of the technology and its clinical effectiveness. This limits the opportunity for the adoption of innovative technology in the early adoption stage since there is only limited outcomes information available from the innovators. However, this study identified multiple opportunities to help improve the Canadian healthcare system in procuring new technologies at the early adoption stage.

Prioritization Criteria in Canada

CADTH, created in 1989, is the main agency that coordinates an approach for all HTAs to produce evidence-informed recommendations that will assist decision makers and benefit patients (25). CADTH has identified priority setting criteria for new technology assessment and adoption based on the EUR-ASSESS project and then conducted a multiple-criteria decision-making (MCDA) to weigh the criteria and identify priorities based on the weights after consultation with selected committees (12, 26). The assessment was based on all new technologies and drugs; and the selected committee members were mainly representatives from federal, provincial, and territorial publicly funded drug plans and pharmacists working for the ministries of health (12). No surgeons/physicians were included in these committees who are considered the ultimate users of these technologies. The CADTH study revealed that the clinical impact of technologies carries the highest weight for decision-makers, followed by (in descending priority order): the burden of disease, the economic impact, budget impact, availability of evidence and alternatives for the technology (12). The process for device use in Canada requires that the product receive Health Protection Branch of Canada (HPB) approval or HPB approval for a batch release to conduct a clinical trial.

The "value" in decisions

Value is broadly known as the ratio of quality to cost, but this varies among healthcare stakeholders (7). The global landscape view on value has challenged leaders to explore new models to engage clinicians for shared risk and rewarding successful adoption for improved patient outcomes. Such value committees are growing today more than ever due to the pressing global challenges from natural threats, industrialization, globalization, economic pressures and changing patients' needs. In Canada, there has not been a comprehensive study that explores the prioritization criteria for decision-making for surgical technology early adoption from the surgeon's perspective. Also, the criteria presently used for technology adoption is most applicable during and after the early majority stage, when clinical outcomes and longer-term follow-up become available. They do not specifically address the criteria to adopt technology in the early adoption phase, when there is limited outcome data from the innovators, that only make up 2.5 percent of the users. Involving surgeons, the end-users, and making them part of such decisions, or even developing a criteria framework based on surgeon's decisions in the evaluation of new technologies, would be a more tailored approach that would eventually benefit patients (7). The IDEAL framework has proposed the assessment of surgical innovation based on a five-stage description of the surgical development process; innovation, development, exploration, assessment, and long-term study (8). Early adopters can be involved in the development and improvement of the technology but are primarily involved very early in the exploration phase. This phase uses early and limited prospective and collaborative cohort studies to focus on the learning curve, the indications for the innovation and its quality. These criteria are some of the assessment tools identified in our review, specifically in the categories of clinical outcomes, physician specific and technology specific. This can prompt the development of controlled trials in the exploration stage where the learning curve can affect surgeons' involvement in these studies since they can identify relevant outcome measures (8). These measures would be crucial for research databases and trials and would include technical, clinical and patient reported outcomes to help provide further information about the technologies used and guide other surgeons for making informed decisions (8).

The limitations of this study would help prompt further research in criteria prioritization. There was a lack of any quantitative metrics for criteria weighting based on the results we found. This makes it challenging to identify which criteria are considered a priority over another. Another limitation is that the results found may not represent all of Canada since most of the results found were attributed to only four provinces' HTA reports. Most of the studies and reports did not factor in the surgeon's perspective and priorities in technology adoption. In addition, many of the studies in the literature are older and it is unclear how well, or if they are reflective of current practice. However, it does indicate the need for further studies that explore the changing dynamics of health systems and patients' needs. More research is needed to challenge and validate the criteria using quantitative metrics to weight and prioritize them for guiding surgeons with informed decision-making for the early adoption of new surgical technologies in the Canadian healthcare system. As well, the relative weight of each criterion may vary by geographic region, healthcare system and hospital.

Conclusion

The economic and clinical impact of new technologies are the two most important criteria for technology adoption in healthcare in Canada. The findings of the scoping review have also highlighted some of the deficiencies in the present literature. Value assessment committees should include surgeons in the decision-making process and more research is needed for a comprehensive study that would explore the surgeon's perspective in criteria prioritization for technology adoption. Further studies are needed from other provinces to help have a representative set of weighted criteria that would be applicable to the entire country. Specific criteria for decision making in the early adoption stage of novel technologies are lacking. These criteria need to be identified, standardized, and applied in order to provide innovative, and the most effective healthcare to Canadians.

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.TABLES and FIGURES

Count	Search terms	EMBASE	MEDLINE
1	**("decision making" OR opportunit* OR challenge OR "health technolog* assessment" OR "adoption curve" OR adopt* OR innovators OR "early adopters"**).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	1652285	1153633
2	**(Surgery OR "surgical intervention" OR surgical OR neurosurgery OR orthop?dics OR urology**).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	4663610	3281573
3	**("Canadian health system" OR "Canadian healthcare system" OR "Canada health system" OR "Canada healthcare system" OR Canada OR ontario OR quebec OR alberta OR "british columbia" OR manitoba OR Saskatchewan OR yukon OR "New Brunswick" OR "Newfoundland and Labrador" OR Northwest Territories OR "Nova Scotia" OR Nunavut OR "Prince Edward Island**").mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms]	294214	227802
4	1 AND 2 AND 3	2617	1578

Table 1: Search strategy using MEDLINE database

Table 2: Data extraction from database search

Author, year (Location)	Level of evidence (Study type)	Surgical specialty (Technology)	Stage on the adoption curve / Decision process framework	Decision making criteria and process / opinion	Challenges	Opportunities	General applicability
1. Goeree, R - 2009 (Ontario)	NA* (HTA** (policy review)	Coronary Artery Disease (Drug eluting stents)		Cost, social, ethical values, legal issues, feasibility of implementation. Quality, safety, efficacy, effectiveness, value for money	Even after careful consideration of the evidence from well-conducted HTAs, decision makers may still have residual uncertainty around a number of issues	Provide a useful evidence-based framework for decision making. Primary data collection is often considered a supplement to evidence available from traditional HTAs.	The HTA process in Ontario represents an interesting adaptation to the traditional HTA approach because primary data collection is used to supplement the HTA, and the iterative evidence-based PRUFE framework, through the use of VOI analysis, is used to help determine research feasibility and data collection needs within studies
2. Borowski, 2007 (Alberta)	NA, (HTA review)	Several (Several)	Alberta Heritage Foundation for Medical Research	Social/demographic, Technological, Environmental, Economic, Political (STEP), Legislative and Ethical considerations	Some HTAs did not include the STEP framework that is now in use. The original framework included five elements: population health impact,	It could enhance the prominence of evidence, while enabling decision makers to do the balancing required for policy formulation	The Alberta Health Technologies Decision Process has greater chance for success in informing policy, because it recognizes that policy and decision makers in government prefer to incorporate or balance

					technological effectiveness, economic evaluation, implementation issues, and policy analysis. We found that some elements could be combined or addressed more fully at other points in the process		other factors and information beyond hard evidence when making decisions
3. Danjoux, M - 2007 (Ontario)	4 (Case study)	Abdominal aortic aneurysm (Endovascular aneurysm repair)	Accountability for Reasonableness	Relevance, publicity, appeals, enforcement. – Medical individualistic perspective	Not generalizable for smaller hospitals, small sample size	1. Hospitals should develop a structure for deliberating the reasons for adopting a surgical innovation that involve a wide range of stakeholders. 2. Broader input should be sought from individuals involved with the procedure and those at "arms length" who may not be directly invested in the innovation. 3. Hospitals should establish a formal appeals	NA

						mechanism for addressing challenges to the decisions being made.	
4. Lehoux, P – 2012 (Canada)	4 (Case study)	Several (Several)	Socio-technical dimensions and features (prevention, efficiency, sense of security, real-time feedback, ease of use, flexibility)	Clinical (Impact on clinical activities and outcomes), Technical (Technical assets and comparison with technological alternatives), Structural (Impact on work processes and health care structures), human (Response to clinicians' and patients' values, expectations and constraints)	Lack of ethical appeals, evidence, lack of universal strategies	Manufacturers' websites can bolster physician and patient expectations that can then be easily used to put pressure on third-party payers	Our study also showed that the valuable socio-technical goals and features that manufacturers invoke are, at first glance, in tune with the challenges of modern health care systems. However, the reference to these values is clearly more rhetorical than demonstrative
5. Poulin, P – 2012 (Alberta)	NA (Review)	Several (Several)	Based on HTA Calgary Health Region program	Health gain (efficacy, population health, standard of care), Service delivery (safety, training, access, service coordination), Sustainability (long term), Strategic fit	HTA program lacks patient and public input.	Local HTA Program is positioned to help bridge the gap between evidence and practice, by providing a way to incorporate global evidence with local relevance and involving surgeons themselves. Hospital-based HTA using local data can fill gaps in	We believe that the program is generalizable to other health care organizations that require integration of local contextual information with research evidence as provided in external HTA reports. The Program has sufficient versatility to be

				(good alignment with local values), Innovation (Knowledge and research), Financial (cost, economic analysis)		the published evidence and also improve the generalizability of evidence to the local setting. Hospitals should maintain easy access databases.	adapted to a wide variety of regional health authorities.
6. Sharma, B – 2006 (Ontario)	4 (Case study)	General surgery (Advanced laparoscopic surgery)	Accountability for reasonableness	Relevance, publicity, appeals, enforcement	Recall bias, social desirability bias	Ways to improve the fairness and legitimacy of decision making, including (1) publicizing the process and results of decisions about the adoption of new surgical technologies, (2) clarifying and publicizing the role of the hospital board in providing a structure for appeals of decisions, and (3) impaneling a group of stakeholders, with public representation, to oversee the decision-making process. Our findings will help physicians and health care administrators improve the decision-making processes for innovative surgical technologies	Observations based on one community hospital and not generalizable

7. Urquhart, R – 2014 (Nova Scotia)	4 (Case study)	Several (Several)	Organizational framework of innovation implementation	Management support, financial resource availability, implementation policies and practices, implementation climate, innovation champions, and innovation-values fit	A number of key informants stated it was difficult to remember what happened during the implementation period. Therefore, the data are subject to issues of recall bias.	The findings revealed that positive relationships can counterbalance many negative contextual factors—thus, the early engagement of key stakeholders across multiple levels of healthcare organizations and systems may be fundamental to implementation efforts and to supporting the consistent and committed use of an innovation. The findings also demonstrate the importance of a multi-level contextual analysis to gaining both breadth and depth to our understanding of innovation implementation and use in health care.	Given that the structure and socio-political context of healthcare systems vary, this may limit the applicability of findings to other jurisdictions. Nonetheless, healthcare systems generally have a number of defining features, including a wide range and diversity of stakeholders, complex governance and resourcing arrangements, and high degrees of professional autonomy of many of its staff, which should increase the applicability of these findings in other health systems

* NA: Not applicable
* HTA: Health Technology Assessment

Table 3: Data extraction from provincial websites

ITEM	ALBERTA	BRITISH COLUMBIA	ONTARIO	QUEBEC
No. of studies	32	22	302	415
Surgery related studies	11	7	90	40
Agency Name	AHT - DP (Alberta Health Technologies Decision Process)	HTR (Health Technology Review)	HQO (Health Quality Ontario) Evidence, Developments and Standards Division	INESSS (Institut National d'Excellence en Santé et en Services Sociaux)
HTA* method	Systematic review - Economic evaluation - Budget Impact Analysis			
Criteria	Social and system demographics (incidence/prevalence - service delivery capacity)	Social and system demographics (disease burden - population impact - training and credentialing required)	Social and system demographics (disease burden - need)	
	Clinical effectiveness (Health and non-health effects)	Clinical effectiveness (Health and non-health effects - quantity and quality of life)	Clinical effectiveness (Safety - effectiveness)	Clinical effectiveness (Safety - effectiveness)
	Political and public policy considerations	Political and public policy considerations (access - environmental impact - prevention - risk to implementation - impact on marginalized/disadvantaged patients)	Political and public policy considerations (societal and ethical values)	
	Costs	Costs	Costs	Costs

			Feasibility of adoption into health system (economic - organizational)	

* HTA: Health Technology Assessment

Table 4: Categorization of criteria for decision-making

CATEGORY	CRITERIA
1. ECONOMIC	1. Cost of technology 2. Economic impact
2. HOSPITAL SPECIFIC	1. Feasibility of implementation 2. Structural / management support 3. Strategic fit 4. Relevance 5. Standards of care 6. Service coordination
3. TECHNOLOGY SPECIFIC	1. Technology simplicity 2. Innovation 3. Quality 4. Real-time feedback 5. Efficiency
4. PATIENTS / PUBLIC	1. Population health impact 2. Human responses (patient experience) 3. Publicity and awareness of technology 4. Access to technology 5. Social / demographic
5. CLINICAL OUTCOMES	1. Safety 2. Efficacy 3. Effectiveness 4. Adverse events and prevention
6. POLICIES AND PROCEDURES	1. Ethical 2. Legislative 3. Environmental 4. Sustainability 5. Political 6. Appeals 7. Enforcement
7. PHYSICIAN SPECIFIC	1. Sense of security 2. Flexibility of usage 3. Innovation champions 4. Training

Figure 1: PRISMA (Scoping Review) flowchart

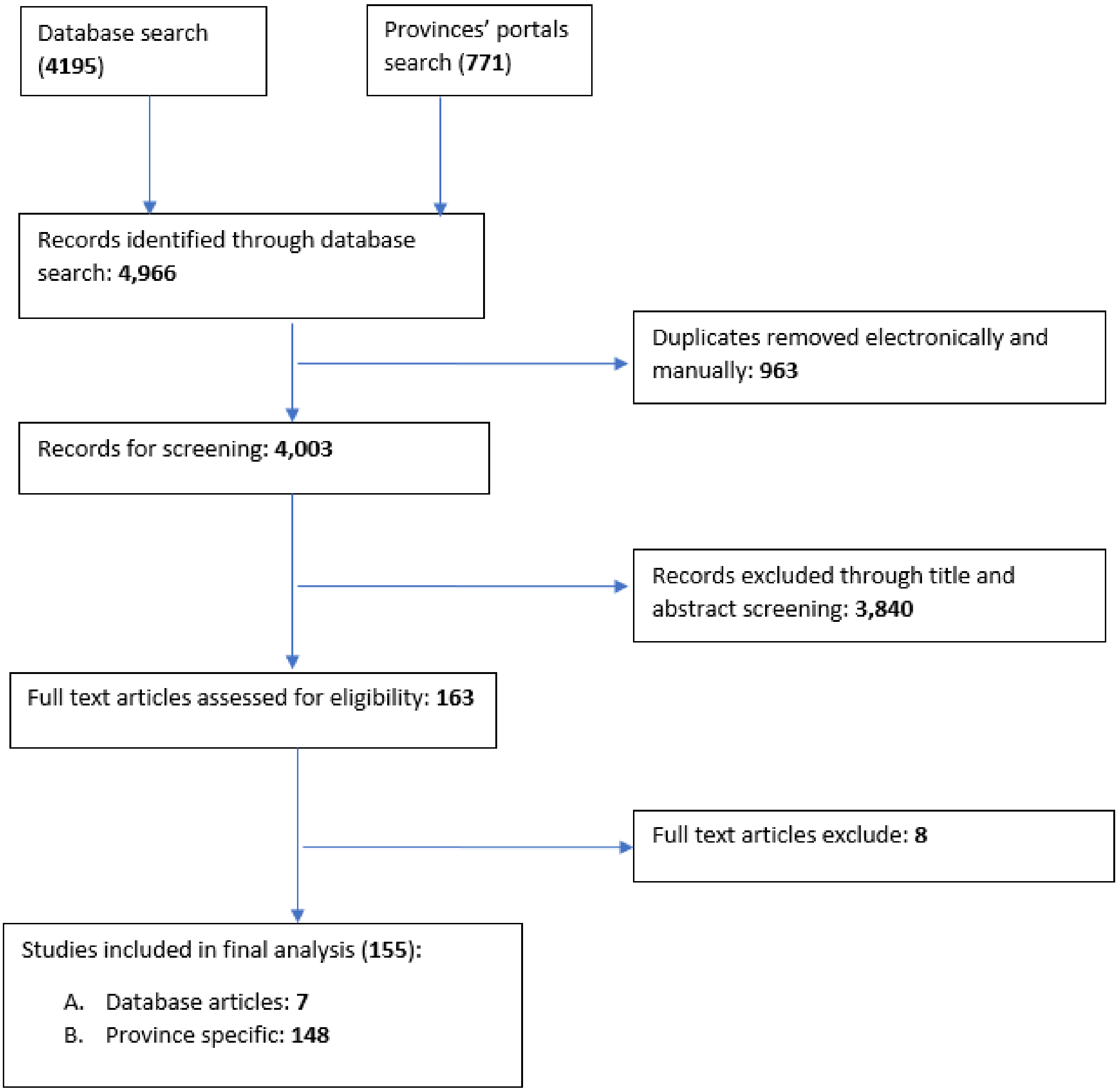
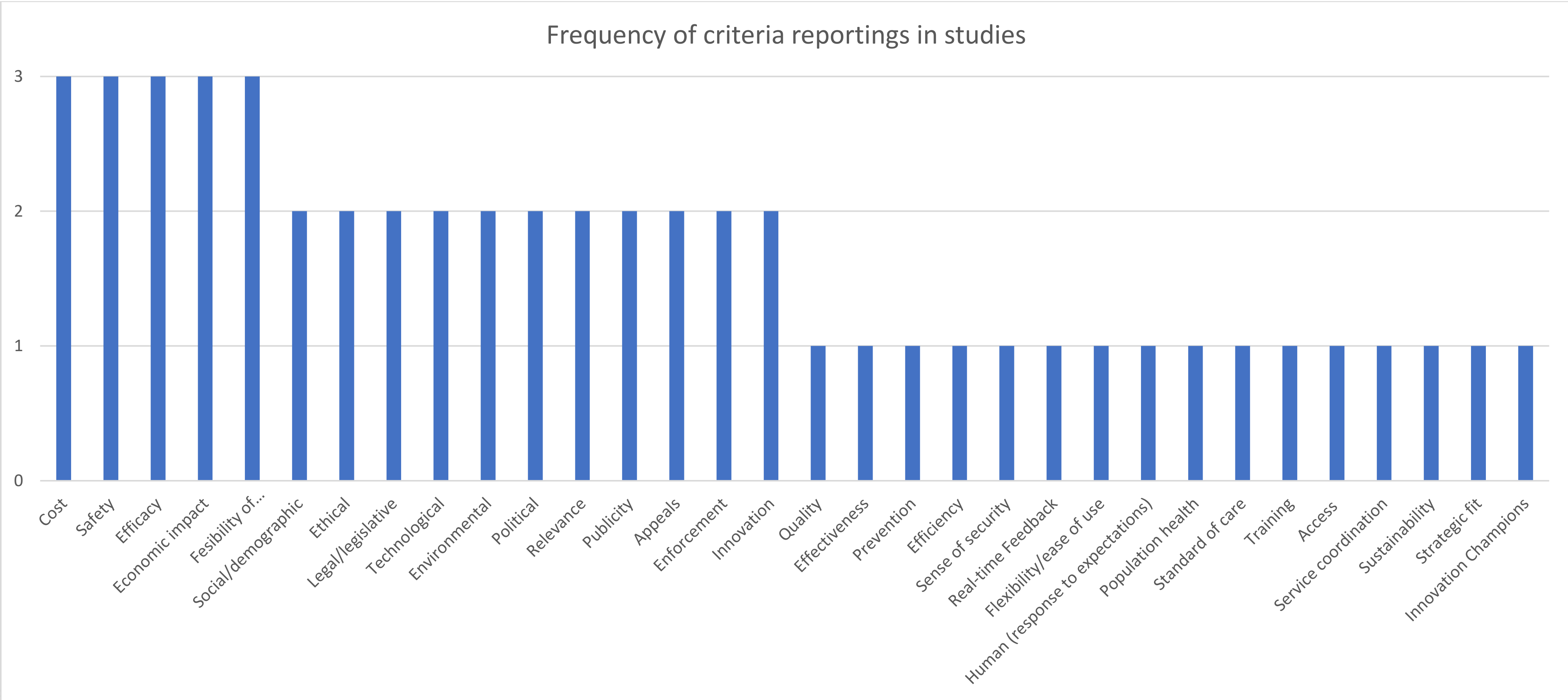


Figure 2: Frequency of criteria reporting from studies



BRIDGING STATEMENT BETWEEN MANUSCRIPT ONE AND MANUSCRIPT TWO

In manuscript one, we did a comprehensive scoping literature review to identify the current existing criteria used in Canada to guide the decision for the early adoption of a new surgical technology. These criteria were found from the published literature and from all provincial websites (including health technology assessment portals) that focused only on the Canadian context.

The results of the study identified 33 sub-criteria used and were categorized by themes under seven main criteria categories. These criteria were not yet validated and lacked quantitative analysis on which is considered a priority to help guide decision-makers to adopt new surgical technologies in the early adoption phase into the Canadian healthcare system. This prompted the development of the second manuscript to further analyze these criteria, validate them and create weightings to guide decision-makers.

In the second manuscript, the 33 criteria were validated and prioritized. Questionnaire one was developed and sent to experts. These experts validated the 33 sub-criteria and added 11 more sub-criteria, resulting in 44 sub-criteria. Then, the results were analyzed, and the 44 sub-criteria were classified under the seven main criteria categories, called domains. Questionnaire two was then developed and sent to an expanded group of experts. These experts were then asked to compare the seven main domains based on a pairwise comparison matrix using a 9-point Saaty's scale, where one indicated equal importance between the two criteria being compared and nine indicated absolute importance of one criterion over the other by comparing each domain against the other. Then, they were asked to rank the 44 sub-criteria using the Likert scale with one being an irrelevant criterion and five being an absolutely relevant criterion. All quantitative results were then fed into the developed Multi-Criteria Decision Analysis (MCDA) model to determine the priority weights for each domain and priority rank for the sub-criteria. This helped to develop a list of the priority criteria based on a comprehensive quantitative analysis. This will help guide decision makers for priority setting for the early adoption of new surgical technologies into the Canadian healthcare system using the weighted, prioritized and ranked criteria.

CHAPTER 5: MANUSCRIPT 2

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Prioritization and Ranking of Decision-Making Criteria for the Early Adoption of Innovative Surgical Technologies

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KEY POINTS

Question

What are the relevant weighted criteria that decision-makers can use to make an informed decision for the early adoption of innovative surgical technologies?

Findings

In this multi-criteria-decision-analysis study, clinical outcomes were considered the most important criteria to guide surgeons and non-surgeons in the early adoption of new surgical technologies. Responses from surgeons and non-surgeons were similar, indicating that all stakeholders have similar priority-setting criteria.

Meaning

Utilizing multiple prioritized and weighted criteria is indispensable in making informed decisions in the early adoption of new surgical technologies to judiciously use financial resources and maximize patient outcomes.

ABSTRACT

Importance

Currently, there is no decision-making framework in the early adoption stage of novel surgical technologies, putting the quality of healthcare and resource allocation of the healthcare system at risk.

Objective

To establish the relevant weighted criteria that decision-makers can use to make an informed decision for the early adoption of innovative surgical technologies.

Design

This mixed methods Multi-Criteria Decision Analysis (MCDA) multi-institutional study had two phases. First, an expert panel of 12 validated decision-criteria in the literature and identified additional relevant criteria. Second, 33 Canadian experts prioritized the main criteria (domains) using the composition pairwise-comparison weight elicitation method (Analytical Hierarchy Process Model) and ranked their sub-criteria using the direct ranking elicitation method, (Likert scale). Data was then analyzed, and responses' consistency was estimated using the consistency ratio (CR). Analysis of Variance (ANOVA) was used to assess for significant differences between all expert responses.

Setting

The MCDA was conducted at McGill University between 2021-2023. Data was collected nationally by inviting experts in Canada.

Participants

Male and female experts were invited with different levels of education (MD or equivalent, Masters, or PhD degree) and with different years of experience (<10, 11-20, 21-30 and >30 years). Surgeon experts were from all surgical disciplines and non-surgeon experts were administrative officers in surgical devices procurement, health technology assessment experts, and hospital directors.

Main outcome and measure:

Criteria domains weights and sub-criteria rankings.

Results

Seven domains and 44 sub-criteria were identified. The MCDA-model found that clinical outcomes had the highest priority vector of 0.429, followed by patients and public relevance (0.135). Hospital-specific criteria (0.099), technology-specific criteria (0.092) and physician-specific (0.087) were the next highly ranked. The lowest priority vectors were for economic criteria at 0.083 and finally policies and procedures at 0.075. There was consensus in the responses CR=0.006 and there were no statistically significant differences between experts' responses.

Conclusions and relevance

This MCDA study weighted priority criteria domains in importance and established ranked sub-criteria to guide informed decision-making for early technology adoption. Putting these criteria into a framework will help surgeons and decision-makers make informed decisions for the early adoption of new surgical technologies.

INTRODUCTION

Continuous innovation in surgery has been crucial in improving patient outcomes, reducing recovery times, minimizing complications, and allowing more effective and efficient surgical care (1). The process of technology adoption over time is typically illustrated as a classical bell curve distribution, with the first group of people to use a new product called innovators, followed by early adopters, the early majority, the late majority, and the last group to eventually adopt a product are the laggards (2). While surgeons are generally risk-averse and favour the status quo, there are surgeons that are early adopters of new products and technologies (3). These surgeons are more likely to be opinion leaders, closely watch for new innovations, embrace technological innovation and are ready to adopt new surgical technology at an early stage (4).

The decision-making process to purchase and adopt new surgical technology is a complex and multi-faceted process that involves multiple stakeholders. This process is not standardized and varies by country and healthcare system. In the USA, after approval by the Food and Drug Administration (FDA), technology adoption is up to the hospital administration and surgical departments (5). In the United Kingdom (UK), after approval by the Medicines and Healthcare Regulatory Authority (MHRA) (6), the National Institute for Health and Care Excellence (NICE) conducts health technology assessments (HTA) and provides guidance, based on their cost-effectiveness analysis (CEA), to the National Health Service (NHS) on which technology is recommended for adoption (7). In Canada, the decision to adopt and reimburse medical devices is decentralized in the publicly funded healthcare system (8). Health Canada's Medical Devices Directorate (MDD) regulates medical devices for human use (9). While HTA is not mandatory, the Canadian Agency for Drugs and Technologies in Health (CADTH) provides information to some provincial HTAs, while other provinces have their own provincial HTA agencies and bodies. Quebec, for instance, has the provincial Institut National d’Excellence en Santé et en Services Sociaux (INESSS) and HTA-bodies across teaching hospitals (10). Ontario also has the Health Quality Ontario (HQO), Evidence Development and Standards Division (10). In these provinces, technologies are assessed based on requests from hospital administrators and physicians (10). The decision-making process in the technology's early adoption lifecycle stage is more difficult, and faces a higher level of risk, due to the limited supporting clinical evidence.

By using evidence-based criteria, decision-makers can evaluate the potential impact of a new surgical technology, weigh the disadvantages, and make an informed decision that aligns with the organization's goals, needs, and resources. The decision criteria used by different governments, HTA bodies, hospitals, and surgeons for the adoption of innovative surgical technology are variable. Although the cost, clinical safety and effectiveness are frequently considered among the most important criteria, numerous other criteria influence the decision-making process to adopt a new surgical technology (11-13). These include criteria specifically related to the technology, the surgeon, the patients being targeted, the hospital and the healthcare system (14-15). For example, in the highly competitive US healthcare system, one important criterion is the potential benefit of adopting a novel surgical technology to promote itself as a cutting-edge institution and centre of excellence and thus, accept higher volume of patients (16). In Canada, other criteria include the disease burden, equity of access and the feasibility of implementation (10).

The adoption of new surgical technology involves many complex and interrelated factors. The weighting of criteria is an essential step in the decision-making process because it simplifies the process by prioritizing the most relevant factors and allows for a more objective decision that aligns with the organization's goals and priorities. These criteria may be weighted differently by different organizations based on their specific goals, priorities, and resources. Additionally, different organizations may have their own unique criteria that are specific to their needs and circumstances. Currently, there is no decision-making framework for the early adoption stage of novel surgical technologies. The aim of this study is to establish the relevant weighted criteria that decision makers, including surgeons, HTA experts and surgical administrators can use to make informed decisions for the early adoption of innovative surgical technologies.

METHODS

Study Design and Setting

Decision criteria were prioritized and ranked using Multiple Criteria Decision Analysis (MCDA), in accordance with the International Society for Pharmacoeconomics and Outcomes Research (ISPOR) (17). MCDA is a decision-making tool that considers multidimensional factors and enables comparison of these factors into one overall appraisal. The participants surveyed for this study included three main stakeholder groups: (1) surgeons, (2) hospital administrators involved in the decision-making and procurement of surgical devices; and (3) provincial HTA committee members. All participants were experts in their field, worked in Canada and were identified by the study investigators and by contacting the HTA agencies across Canada (Table 1). After consenting, all experts were sent questionnaires electronically, and responses were collected anonymously.

Selection of decision-making criteria categories

Thirty-three decision-making sub-criteria within seven domains were identified from a previously published literature review of criteria routinely used in the adoption of new surgical technologies (18). In the first round of surveys, 12 experts were sent a questionnaire to evaluate the pertinence of these 33 sub-criteria and determine if further sub-criteria needed to be added. All newly identified sub-criteria were then added to one of the seven domains with the corresponding theme. The final decision-making domains and sub-criteria were evaluated in the second step of the analysis.

Prioritization and Ranking of the Domains

In the second round of surveys, 33 of the 45 experts contacted agreed to participate in the study (response rate of 73%). The experts included 16 surgeons, 6 hospital administrators and 11 provincial HTA committee members (Table 1). Experts were sent a questionnaire that had two main objectives: firstly, to rank the importance of each sub-criteria and secondly, to determine which domain was more important.

Data Analysis and Model Development

Data were analysed using a mixed model methodology which includes domains prioritization by weighting using the Analytical Hierarchy Process (AHP) model and sub-criteria ranking via direct ranking using the direct elicitation method, the Likert scale. To obtain an importance ranking, respondents considered each sub-criteria independently and ranked them on a five-point Likert scale, with one being an irrelevant criterion and five being an absolutely relevant criterion. The responses from the 33 experts were then analysed using the arithmetic mean and the sub-criteria were reordered based on their rankings from the most important to the least important.

Secondly, the domains were prioritized using the compositional pairwise comparison matrix by adopting the AHP model. The AHP is efficient in addressing complex decision-making by helping to establish priorities and choose the best option (19-20). The AHP calibrates the subjective and objective aspects of a decision through its five steps: a) hierarchical structure development, b) pairwise-comparison, c) criteria-weights calculation, d) computation of option scores matrix, e) ranking of the criteria (19-21). A pairwise comparison was used to determine which criteria were more important (19-21). This involved comparing two domains at a time using a 9-point Saaty's scale, where one indicated equal importance between the two criteria being compared and nine indicated absolute importance of one criterion over the other (19-21). The geometric-mean approach was then used to combine the individual pairwise-comparison judgments of the 33 experts into a pairwise-comparison matrix. The AHP model utilized the results of the pairwise-comparison matrix and normalized scores to derive the numerical weights or priorities for each domain allowing the seven domains to be compared in a consistent and rational approach (19-21). The AHP was applied to determine the weights of the relative importance for each domain, the "priority vector".

Statistical analysis

To verify the consistency of the comparisons, the consistency index (CI) was applied for the entire pairwise-comparison matrix (20, 21). The consistency ratio (CR) was then used to determine whether the matrix was sufficiently consistent or not with a random index (RI = 1.32) for the seven categories (n=7) (20, 21). A CR <0.10 indicated that there was consistency within the experts' responses and the matrix is sufficient.

Microsoft Excel - Office 365 package was used to develop the MCDA model and the statistical analysis. A one-way analysis of variance (ANOVA) was performed to test for statistically significant differences between the priority vectors of the domains and the sub-criteria ranked by surgeons only, non-surgeons only and all experts. A p-value <0.05 was considered statistically significant.

RESULTS

In the first questionnaire, experts validated and confirmed that the seven domains and 33 sub-criteria were pertinent. In addition, experts identified 11 new sub-criteria that were important in the decision-making process for early adoption of new surgical technologies and grouped with the 33 sub-criteria identified in the literature (18). The 11 sub-criteria were: cost-effectiveness, depreciation cost, certification of technology, percentage of utilization, maintenance availability, availability of evidence, alternatives available, being an academic center of excellence, evidence of peer-reviewed publications and disease burden. Figure 3 shows the full model and analysis results.

<u>Analysis of domains</u>

Of the seven domains, clinical outcome was determined to be the most important domain, accounting for 42.9% (0.429) of the decision-making process. This domain included the sub-criteria: safety, efficacy, effectiveness, prevention of adverse effects, evidence of peer-reviewed assessments and disease burden. This was three times more important than the next most important domain, patients, and public relevance (priority vector, 0.135). The remaining domains each contributed less than 10% to the decision-making (Figure 1).

When a sub-analysis for surgeons only was conducted, the clinical outcomes domain was also found to have the highest priority vector of 0.425. This was also followed by patients and public relevance with a priority vector of 0.12. Next was physician-specific (0.113), technology-specific (0.112) and hospital-specific (0.107). The lowest priority vectors were also found with policies and procedures (0.066) and finally economic domains (0.059).

In a sub-analysis including non-surgeons only, the clinical outcomes domain was again found to have the highest priority vector of 0.242, followed by patients and public relevance with a priority vector of 0.184. This was followed by policies and procedures (0.135), economic (0.133) and technology specific (0.121) domains. The lowest priority vectors were hospital specific (0.110) and finally physician specific (0.075).

Sub-criteria analysis

Overall, safety was ranked as the most important of the 44 sub-criteria with a score of 4.939, followed by effectiveness (4.909), efficacy (4.758) and feasibility of implementation (4.605). The first three sub-criteria are all within the clinical outcomes' criteria domain. The lowest scoring sub-criteria were appeals (2.818), depreciation cost (2.774) and political impact (2.667) (Figure 2 a-b).

The sub-analysis of surgeons only identified safety as the most important sub-criterion (4.941), followed by effectiveness (4.882), being an academic center of excellence (4.813), and efficacy (4.706). The lowest scoring sub-criteria were appeals (2.941), depreciation cost (2.688) and political impact (2.588).

The sub-analysis for non-surgeons only identified that safety and effectiveness were equally the most important sub-criteria (4.938) followed by efficacy, feasibility of implementation and structural management equally at 4.813. The lowest scoring sub-criteria were political (2.75), publicity and awareness and appeals (2.688).

The consistency of the comparisons using the CR was found to be 0.006 ($CR<0.1$), indicating that there is consistency within the experts' responses and the matrix is sufficient. In addition, the statistical analysis using ANOVA comparing the difference between the groups' responses was not statistically significant indicating that the priority vectors from all experts' responses can be used as the weights to guide decisions for surgeons and decision-makers to adopt a new technology into the healthcare system.

DISCUSSION

Using an MCDA methodology, this study identified 'clinical outcomes' as the most important domain in the early adoption of new surgical technologies into the healthcare system, accounting for 42.9% of the decision-making process. Safety, effectiveness, and efficiency were the most important individual sub-criteria influencing decision-makers. Although there was some disparity in the rank order of the importance of each domain between surgeons, HTA committee members, and hospital administrators, there was a consensus in establishing nine of the ten most important sub-criteria.

This study's finding that clinical outcomes are of principal importance when deciding to adopt a new surgical technology aligns with the rationale of adopting technologies to improve patient care, as well as with the previous literature. Patient safety and effectiveness are considered by surgeons to be the most important factors in adopting new technologies (13, 22). Non-surgeons, including policy-makers and HTA experts, concur that clinical outcomes are the most important determining factor (23, 24) since clinical outcomes are the mainstay for determining health-related quality of life and life expectancy (22, 25). However, previous studies do not consider the technology adoption life cycle. In the early adoption phase, the extent of clinical outcomes information is limited and may comprise only a few publications and conference presentations. This does not negate the importance of clinical outcomes but suggests that the expectation of having definitive scientific confirmation may need to be less than if the technology is being assessed in a later stage of its life span.

The results from this study have several policy implications. Firstly, the agreement between surgeons and non-surgeons involved in the procurement of new technology indicates that the decision-making criteria can be harmonized. Surgeons are the primary users of the technology and have a deep understanding of the technical aspects of the procedure and the needs of the patient, while non-surgeons, such as administrators, have a broader perspective on the financial and organizational aspects of the technology adoption (26). Agreement by both groups suggests that the criteria being used to evaluate the technology are relevant and appropriate, and that they consider the different perspectives and expertise of both groups. Since healthcare systems can differ between countries, it would be reasonable if the criteria differed between healthcare systems, but it should be consistent within each (4, 11, 12, 14).

Secondly, technology assessment appraisal committees (HTA bodies) should include representation of all stakeholders in the decision-making committee, including surgeons. Surgeons play a critical role in the identification of new technology in the early adoption phase since the clinical results may primarily be from conferences and individual communications, rather than from extensive published literature, that would be available only in the later stages of the technology life cycle (26). This information can provide important insight into the indications and benefits of the new surgical technology. In addition, surgeons are the primary users of the technology, they have a deep understanding of the technical aspects of the procedures, the needs of the patients, and the local environment (13, 26, 27).

Thirdly, this study demonstrated that not all criteria are, or should be, equally weighted in importance in the early adoption of a new surgical technology. Not all criteria are considered as critical since they may have different levels of impact on patient outcomes and the overall success of the technology. By assigning different weights to different criteria, decision-makers can ensure that the most important factors are given the most consideration when making decisions about new surgical technology adoption. The importance of weighing each criterion is particularly relevant since the cost of the technology is commonly felt to be a primary criterion in which decisions are made (16, 23, 24).

Fourth in this study, the economic and policies and procedures domain were the least important domains and cost of the technology ranked 32 of the 44 sub-criteria. The cost of technology should be considered in the long-term, rather than just the upfront costs. A technology that may have a higher upfront cost but leads to better patient outcomes and fewer complications in the long-term may ultimately be more cost-effective. However, not considering indirect costs, such as additional staff or equipment needed to support the technology and increased operating time may lead to underestimating the true cost of the technology. CEA tend to use endogenous costs of technologies (final costs for payers) in its analysis rather than exogenous costs which reflects true production costs (28). This undermines the value of CEA that relates to the best use of resources for maximal health benefits (29, 30). The opportunity cost would be less societal benefits for alternative resources without maximizing health outcomes (29, 30). This implies that CEA would not be considered an optimal method alone in HTA to influence decisions on technology adoption.

Although this study has been designed with a mixed model methodology to include the perspectives of several stakeholders, there are some limitations. First, the domains and sub-criteria identified from the literature included in this study come from the limited number of studies found which might not capture the full spectrum of relevant domains for all hospitals. However, the first step in this study was to validate the domains in the literature and determine if others should be included. This resulted in 11 additional sub-criteria added to the analysis. All the domains analysed in this study are currently used in part by technology assessment committees. Second, the adoption criteria for new surgical technology were determined by pairwise-comparison matrices and the experts' responses may, in part, be a reflection of the Canadian healthcare system in which they presently work. This might affect the generalizability of the relative weight of each sub-criteria in other countries with different healthcare systems. Nonetheless, this study highlights the need for weighted domains in the decision-making process. Third, the prioritization and ranking of domains and sub-criteria for the decision-making for the adoption of innovative surgical technology needs to be a dynamic process. The domains and weights identified in this study reflect a static assessment of the present surgical and hospital priorities and should be reassessed over time in order to stay current and accurately reflect the technology and patient needs.

Conclusion

This MCDA study found that not all criteria are equally weighted in importance and established weighted prioritized domains that can be used to guide informed decision-making for early technology adoption. There was a consensus between surgeons, HTA committee members, and hospital administrators on the most important decision-making domain. Although we found that clinical outcomes were the most important domain to adopt new surgical technologies, further research is needed for countries with different socioeconomic and geopolitical systems that may have different priority criteria.

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Author contributions:

Haitham Shoman and Dr Michael Tanzer had full access to all the data in the study. Haitham Shoman takes responsibility for the integrity of the data and accuracy of data analysis.

Concept and design: Dr Michael Tanzer and Haitham Shoman

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Drafting of the manuscript: Haitham Shoman and Dr Michael Tanzer

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FIGURES AND TABLES

Figure 1: Priority weights of the seven main criteria domains.

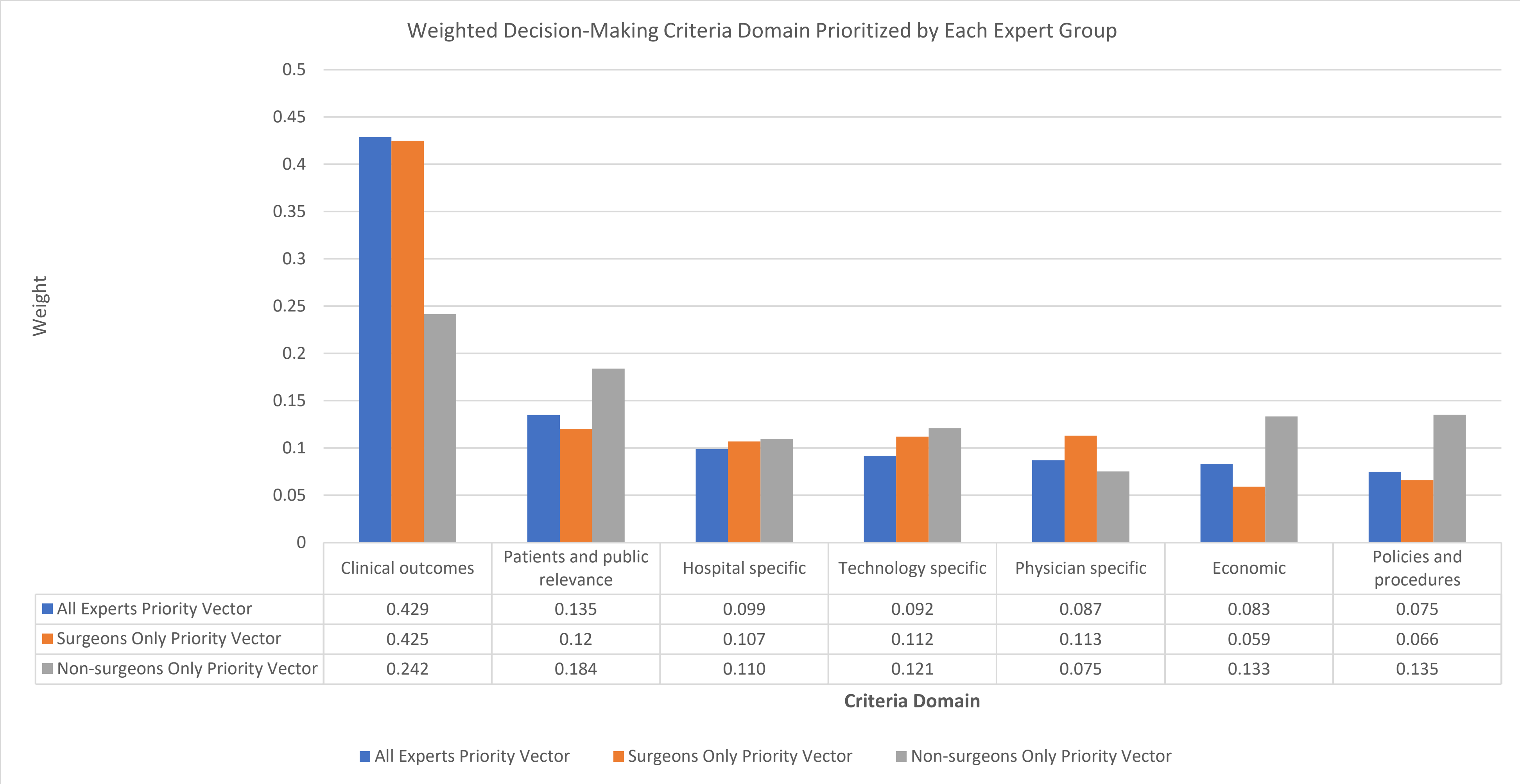
Figure 2: Prioritization of all 44 subcriteria by all experts

- **a-** Sub-criteria prioritized from responses of all experts by their ranks
- **b-** Sub-criteria prioritization according to their criteria domains by all experts

Figure 3: Hierarchical representation of the AHP model of criteria prioritization for surgical technology adoption

Table 1: Demographic analysis

FIGURE 1: Priority weights of the seven main criteria domains.

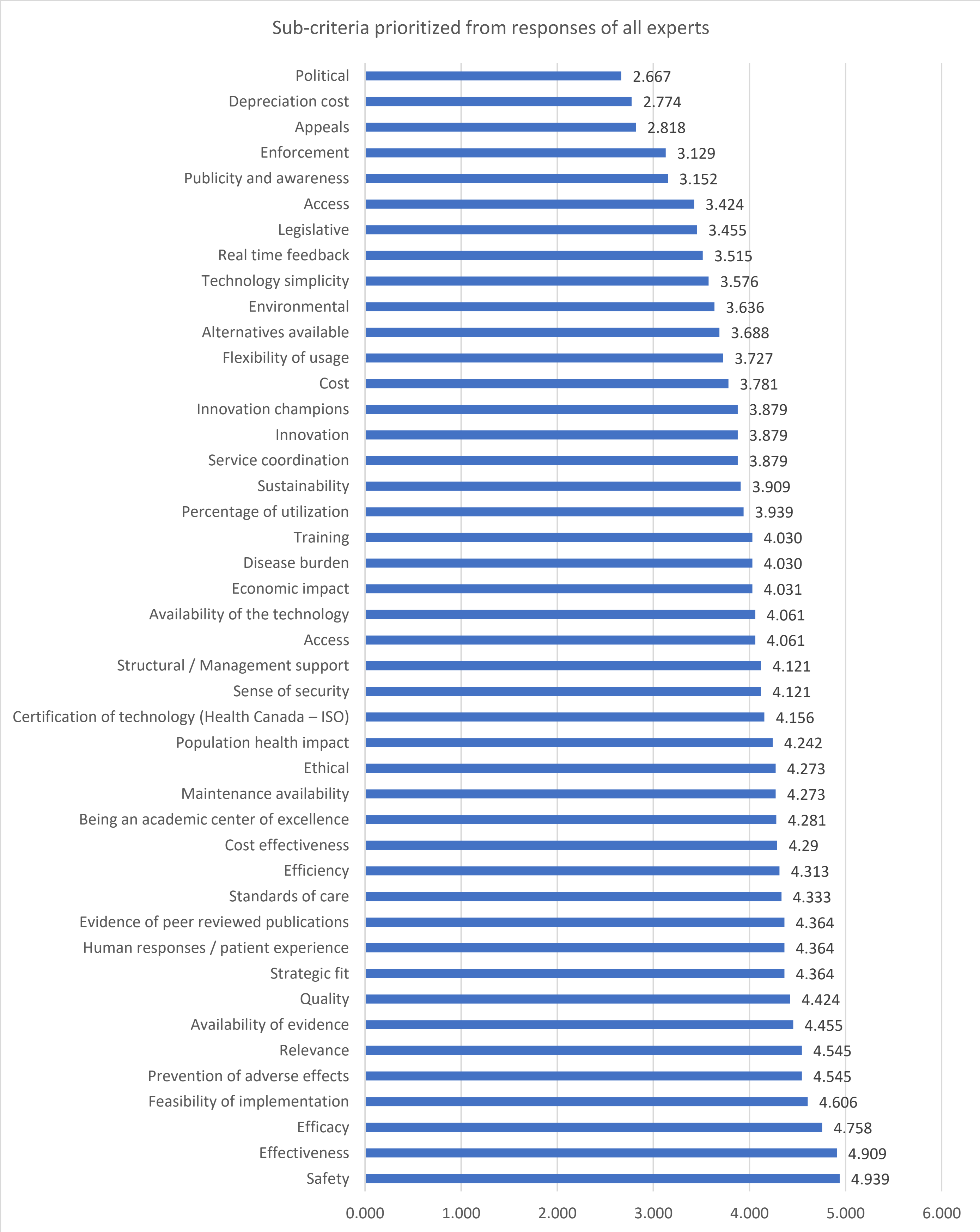


	Clinical outcomes	Patients and public relevance	Hospital specific	Technology specific	Physician specific	Economic	Policies and procedures
All Experts Priority Vector	0.429	0.135	0.099	0.092	0.087	0.083	0.075
Surgeons Only Priority Vector	0.425	0.12	0.107	0.112	0.113	0.059	0.066
Non-surgeons Only Priority Vector	0.242	0.184	0.110	0.121	0.075	0.133	0.135

Priority weights of the seven main criteria domains grouped by all participants (experts), surgeons' only responses, and non-surgeons' only responses.

FIGURE 2: Prioritization of all 44 subcriteria by all experts

A) Sub-criteria prioritized from responses of all experts by their ranks



B) Sub-criteria prioritization according to their criteria domains by all experts

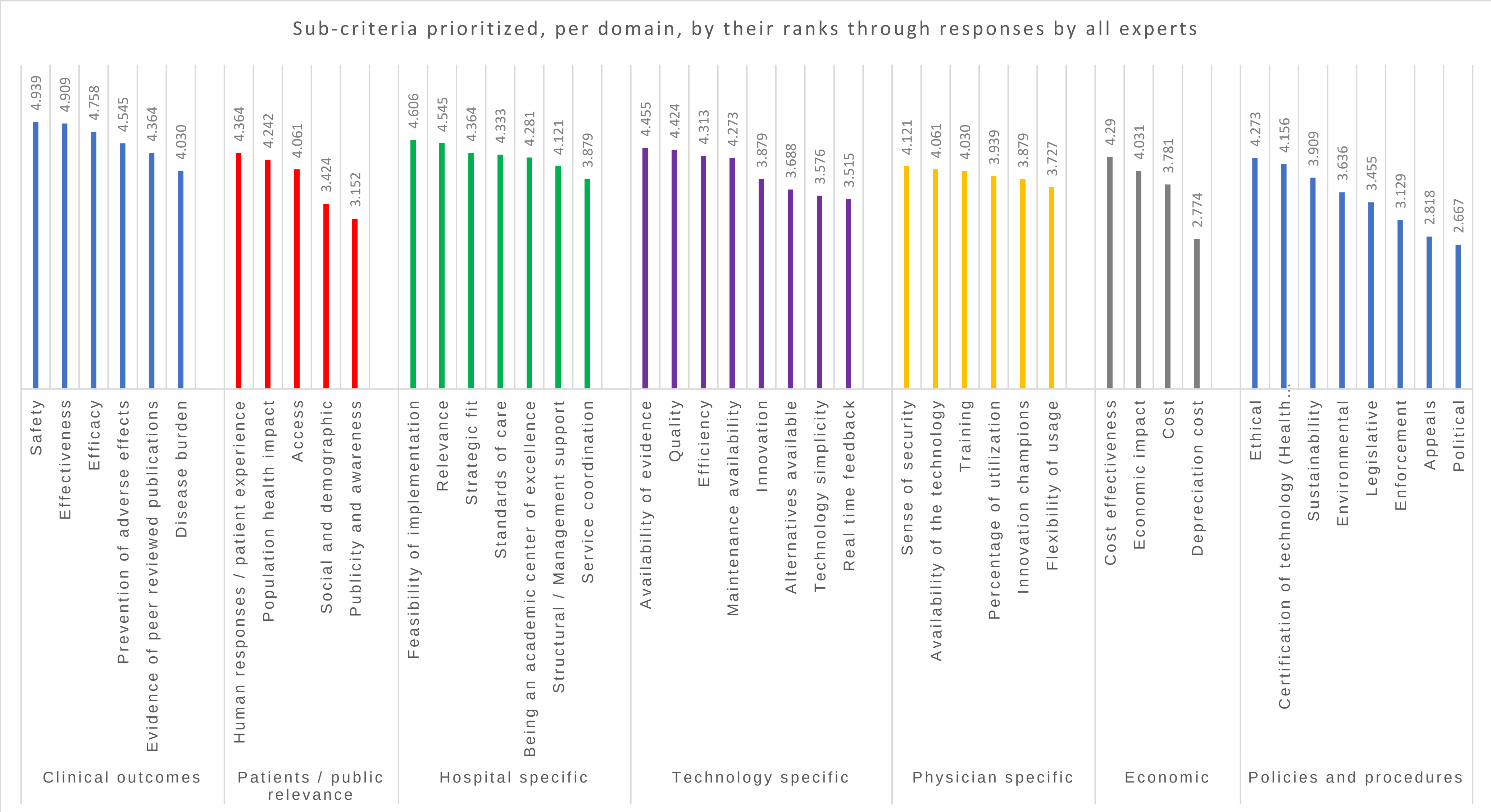


FIGURE 3: Hierarchical representation of the AHP model of criteria prioritization for surgical technology adoption

LEVEL 1 (GOAL)

Adoption of surgical technology 1.00

LEVEL 2 (CRITERIA DOMAIN)

- Clinical outcomes (0.429)
- Patients and public relevance (0.135)
- Hospital-specific (0.099)
- Technology-specific (0.092)
- Physician-specific (0.087)
- Economic (0.083)
- Policies and procedures (0.075)

LEVEL 3 (SUB-CRITERIA)

Clinical outcomes (0.429)

Safety	4.939
Effectiveness	4.909
Efficacy	4.758
Prevention of adverse effects	4.545
Evidence of peer reviewed publications	4.364
Disease burden	4.030

Patients and public relevance (0.135)

Human responses / patient experience	4.364
Population health impact	4.242
Access	4.061
Social and demographic	3.424
Publicity and awareness	3.152
Human responses / patient experience	4.364
Population health impact	4.242

Hospital-specific (0.099)

Feasibility of implementation	4.606
Relevance	4.545
Strategic fit	4.364
Standards of care	4.333
Being an academic center of excellence	4.281
Structural / Management support	4.121
Service coordination	3.879

Technology-specific (0.092)

Sense of security	4.121
Availability of the technology	4.061
Training	4.030
Percentage of utilization	3.939
Innovation champions	3.879
Flexibility of usage	3.727

Physician-specific (0.087)

Availability of evidence	4.455
Quality	4.424
Efficiency	4.313
Maintenance availability	4.273
Innovation	3.879
Alternatives available	3.688
Technology simplicity	3.576
Real time feedback	3.515

Economic (0.083)

Cost effectiveness	4.290
Economic impact	4.031
Cost	3.781
Depreciation cost	2.774

Policies and procedures (0.075)

Ethical	4.273
Certification of technology (Health Canada – ISO)	4.156
Sustainability	3.909
Environmental	3.636
Legislative	3.455
Enforcement	3.129
Appeals	2.818
Political	2.667

TABLE 1: Demographic analysis

N=33	**SURGEONS**	**HTA-EXPERTS**	**OTHERS**
Gender			
Male (24)	14	6	4
Female (9)	2	5	2
Highest level of education			
MD or equivalent (eg: BSc, BA)	10	2	2
Masters	4	4	5
PhD	2	4	
Years of experience			
< 10 yrs	1	3	0
11 - 20 yrs	2	3	3
21 - 30 yrs	9	2	3
> 30 yrs	4	2	1

CHAPTER 6: DISCUSSION OF ALL THE FINDINGS

The evidence surrounding surgical practice and surgical innovations including new techniques, modified strategies, or innovative tools is weaker than evidence for new drug treatments. The number of studies such as randomized trials for surgical innovations have been growing in a slower rate and of poorer quality compared to those coming out for new drugs. The IDEAL Collaboration was then established to improve the evidence base of surgical innovations and developed a framework identifying the stages for surgical innovation (idea (1), development (2a), exploration (2b), assessment (3), and long-term study (4)) (45). It was developed because it was found out that surgical technology innovation follows a pathway that is different from the pharmacological development pathway and thus, a different evaluation approach is needed.

The IDEAL framework could help demonstrate at which stage is the surgical innovation on the technology adoption lifecycle. Surgeons who are in the “idea (stage 1)” stage with a proof of concept considered as the innovators on the technology curve. Those who are under the technology “development (stage 2a)” working on developing the technology are considered amongst the innovators and early adopters. When the technology is under the “exploration (stage 2b)” where it involves learning and comparing results with conventional methods, this is equivalent to the innovators, early adopters, and the early majority on the technology adoption curve. When the technology is undergoing “assessment (stage 3)”, it becomes aligned with the early majority adopters on the technology adoption curve. Finally, the “long-term study (stage 4)” of the technology involves all technology adoption levels since this is where the technology is being audited and undergoes quality assurance and risk adjustment in different places. HTA bodies would conduct their assessments in stages 3 (assessment) and 4 (long-term study) (45).

In addition to ensuring a timely adoption of evidence-based surgical innovations, the use of standardized decision-making criteria may also protect patients and healthcare systems from the detrimental effects of premature adoption of innovations with limited value (high cost, with no [or negative] impact on outcomes). For instance, there were cases where premature technology adoption led to significant patient complications, high recall rates and early phase-out of some devices (46). This posed significant risks to health such as in hip prosthesis and cardiovascular devices in addition to adverse effects affecting women who had new breast implants (46, 47). It is considered challenging to determine when to adopt a new medical device into clinical practice specifically where there is uncertainty on the outcomes of the emerging technology regarding risks and benefits. The premature adoption also poses the question on the ethical concerns regarding informed consent for patients who will have these new devices (48). It is this, important that surgeons are aware of the “optimism bias” and the risk of influence from colleagues and explore relying on the replicability or obtaining consistent results of technologies during the development and assessment stages (49).

6.1 Domains prioritization and sub-criteria ranking

The study utilized a practical approach to guide decision makers for early surgical technology adoption through a MCDA methodology and ranked the priority weights of seven criteria categories (domains) and 44 sub-criteria from responses of 33 participants who are experts in health technology assessment including surgeons, HTA experts, administrators, and decision makers. Analysis from all participants showed that clinical outcomes were the most important criterion category (domain) that influenced decision makers, including surgeons, for the early adoption of new surgical technologies into the healthcare system. This was followed in order by patients and public relevance, hospital-specific, technology-specific, physician-specific, and economic criteria. Policies and procedures were the least important criterion. The top three sub-criteria, which included the most important sub-criteria from the clinical outcomes criteria category, were safety, effectiveness, and efficacy. The least important sub-criteria were enforcement and political, which are from the policies and procedures criterion category, as well as depreciation cost, from the economic criterion category. This was found to be common across all provinces in Canada without any specific order or priority. The purchase of new technology in the Canadian publicly funded healthcare system is ultimately decided by the public hospital and/or province, who primarily consider cost and clinical effectiveness in their decision.

6.2 Surgeons' involvement in technology appraisal committees

Previously, surgeons have not always been included in committees deciding on new surgical technology adoption. Since there is variability in surgeons' preferences for adopting new surgical technologies, even within the same institution, there could be a downstream of challenges that could affect the adoption process (10). This could include raising supply chain costs, which might impact the financial health is the system (10). This necessitates the need for harmonized and standardized criteria for adoption decisions to be used by surgeons.

Surgeons, who are the main users of the technologies, typically initiate a request to the hospital who asks the HTA committees to determine the net positive value and impact of the technology (10). The HTA then conducts the technology appraisal and decide whether to support the technology request (10). The HTA units are often named as “hospital value committees” because they tend to represent the hospital’s best interest in the delivery of the triple-aim of medicine: improving populations’ health, improving the care experience, and reducing costs (10). Through their evolving roles, they are also known to be the gatekeepers for adopting new technologies, based on their tendency to deliver value to the hospital. Hospital value committees could vary in the way they determine value, and its analysis could be based on their assessment criteria developed by their HTA committees (10). A basic hospital value committee would evaluate a new technology based on its cost and clinical effectiveness. A sophisticated hospital value committee would be more clinically integrated by including surgeons, who could offer a better perspective of the clinical outcomes, provide input on the impact of the technology on workflow efficiency, revenue cycle, supply chain impact storage/contracting and risk sharing (10). Surgeons are usually able to track new technologies and measure the real impact of these technologies against hypothesized predictions.

In advanced healthcare systems, these committees should include surgeons who will identify the importance of the technology. This should be based on comprehensive pre-set priority criteria for the adoption of technologies and for a unified decision-making process. However, these criteria might not have included the perspective of the ultimate end-users. Involving surgeons and making them part of such committees, or even developing a criteria framework based on surgeon’s decisions in the evaluation of new technologies, would be a more tailored approach that would eventually benefit patients (10).

6.3 Surgeons and non-surgeons' responses in prioritizing clinical outcomes

Using criteria prioritization and weighting, this study's finding that clinical outcomes are of ultimate importance when deciding to adopt a new surgical technology aligns with the rationale of adopting technologies to improve patient care, and the external literature. Studies on factors influencing the adoption of new technologies have indicated that surgeons consider patient safety and effectiveness as the most important factors (50, 51). Non-surgeons, including policymakers and HTA experts, also share the same perspective that clinical outcomes are the most determining factor (52, 53), since clinical outcomes are the most important factor for determining health-related quality of life and life expectancy (52, 54, 55). This was unanimously reported as a crucial element in new surgical technology since clinical outcomes are the backbone for determining health-related quality of life and life expectancy (52, 54, 55). Clinical outcomes of new technologies are also used in HTA reports and results on their safety, effectiveness and efficacy would only help regulatory approvals such as Health Canada, the Food and Drug Administration (FDA) or the European Conformity (CE) mark to enable them to be marketed and legally used in their respective countries (54).

A study in the US explored how clinical outcomes can help influence surgeons' decisions to adopt a new technology (56). The clinical results were considered the most important factor guiding surgeons' preferences for technology use. They then chose the technology to adopt based on four main domains (in order from most important to least important): 1) Technology/implant, 2) Sales and service, 3) Implant vendor, and 4) Cost/financial considerations (56). Technology and implants were the top domain for orthopedic surgeons because of surgeons' interest in conducting research, exploring the scientific evidence for better patient outcomes and conducting follow-up studies. In addition, the implant design, ease of implementation, longevity in patient and product reputation all play a significant role in ensuring high quality of care and improved clinical outcomes for the patients. The second most important was sales and service. This included the availability of the vendor's implant training program, stability of sales representatives, and their ability to augment operating room staffing and improve case quality and operating room efficiency (56). Also, surgeons would consider the availability of information online for patients along with education-focused seminars/events funded by the vendor. The implant vendor domain came in third place. In this domain, surgeons would consider the vendor's willingness to listen to surgeons' suggestions for product improvement, product innovation introduced, vendor reputation and vendor's willingness to create specialized products that meets surgeons' needs (56). The cost/financial considerations were also the least important domain that surgeons identified would influence clinical outcomes, which is aligned with results in our study (56). This domain considered the cost of the implant and willingness of insurers to adequately reimburse the hospital and surgeon (56).

6.4 Criteria comparison with other countries

Results about clinical outcomes from this study aligns with the UK's health technology adoption process where the National Health Service (NHS) gets most of its adoption recommendations from the National Institute for Health and Clinical Excellence (NICE) (57). Similarly, these criteria were also reported by a study conducted in France by Martelli et al, who surveyed 18 French University hospitals and used MCDA to identify the priorities for decision-making to adopt a new technology (58). Another study conducted by Angelis et al across eight European Union (EU) countries showed that clinical effectiveness and safety are considered amongst the most important criteria for reaching a decision on which technologies to adopt (59). It is worth noting that all these countries follow the HTA structure in assessing new technology to reach a decision of whether to adopt the innovation or not. Countries that also have a National Health Insurance model (like Canada) such as Italy, Sweden, Ireland, Australia and New Zealand tend to have the HTA process drawn towards the same criteria in assessment, but geared more towards the clinical, socio-economic impacts and innovation levels (59, 60). In addition, they consider the burden of disease and ethical matters (59). The well-known EUR-ASSESS project evaluated the HTA system processes and methodologies across the EU countries and after a comprehensive review and analysis, they reported that the most important and common criteria used among the EU are: clinical impact, disease burden and evidence of the effectiveness of the technologies, which is aligned to the results found in our study (61, 62).

However, it is worth noting that all these studies and HTA comparisons from other countries involved committees that were not exclusively surgeons, but rather a wide array of decision-makers that span the healthcare profession ranging from physicians, administrators to governmental personnel. It is also important to mention that these HTAs are not necessarily addressing the adoption of a specific technology early on in the adoption life cycle of the technology, but rather as an overall assessment of the technology. In the US for instance, the adoption behavior of surgeons for new technologies is based on their access to new information and their human capital attributes (63). Another example from the Middle East, where in the United Arab Emirates, government support, knowledge sharing, and infrastructure are amongst the most important motivators for technology adoption (42). The early adoption of new technologies would prompt the diffusion of the technology in hospitals and is seen by some places as crucial to distinguish them as a location for academic and clinical excellence, such as using the da Vinci robot in the Netherlands and robots use for prostatectomies in the US (64).

6.5 The lost value in cost-effectiveness

Our study found that the economic, and policy and procedures criteria are the least important for adoption decisions. This could be explained by the fact that currently cost-effectiveness (CE) studies tend to use endogenous costs of a technology in their calculations which includes the final cost for payers, rather than the exogenous costs which reflect the production costs (65). If the technology lies within the CE threshold, they would be adopted. However, manufacturers/suppliers may have less exogenous costs, which are resource costs used for production, and would tend to alter and adjust their price to reach the threshold level set by payers (65). Even though theoretically it is considered a cost-effective technology, it undermines the true principle of CE which relates to the best use of resources for maximal health benefit (65, 66). This would lead to less societal benefit of budgets for alternative recourses (65, 67). Hence, policies that tend to utilize endogenous CEA aiming for maximal CE, might in fact lower it because pricing may react in different ways to the strict pricing procedures (65, 66). Moreover, HTAs and policies for technology adoption based on endogenous CEA could lead to adoption of technologies with higher production costs, leading to draining of fixed budgets without maximizing health outcomes (65). This implies that CEA would not be considered an optimal method alone in HTA to influence a decision on technology adoption, which is subject to the Lucas critique (68). In addition, Canada doesn’t have a universally agreed and set willingness-to-pay (WTP) threshold for CEA. Therefore, having a bar to limit prices by companies does not exist. where in the UK, the WTP threshold is up to 30,000 GBP per quality adjusted life year (QALY) (55). It is also worth noting that If a technology costs more but decreases length of hospital stay and patient complications, it may actually cost less at the end of the day in the long term for both the hospital and patients. This extends from reduced re-admission rates and needs for further treatment plans.

6.6 Strengths and limitations of the MCDA and AHP model

The MCDA is a very useful process in offering a practical real-life, apparent and unbiased priority-setting practice for institutions having multiple criteria and decisions that need prioritization for informed and guided decision-making. The MCDA is a transparent process for decision-making that can also be used to help invite further discussions on policies for priority setting across major disciplines while considering the complexities that decision-makers face (50). Using the MCDA process explores a wider set of criteria and helps provide a deeper analysis on these criteria that extend beyond only cost and clinical effectiveness used by HTA units for priority setting. This is crucial in modern and advanced healthcare systems that are always looking to improve patient outcomes and the quality of care. The strengths of our AHP model in this study include the use of a deliberative process involving key stakeholders, and its flexibility, because the scores and priorities are drawn from the pairwise-comparisons of criteria. Using the AHP helps ensure an unbiased and rational approach in priority setting. Decision making with weighted criteria to base decisions in HTA is a complex process calling for the assimilation of diverse concepts. The AHP computations are guided by the expert's experience and can help consider qualitative and quantitative assessments into a multi-criteria ranking (42, 52). This demonstrates the powerful nature of the model to derive ratio scales and identify priority weighted criteria to facilitate decision-making.

There are also some limitations worth noting. The first limitation is that the AHP model is used to support decision making using the aggregate responses from experts based on a large number of questions sets asking the expert “which of the two criteria is considered a priority on the other for your decision-making?”. While these questions are crucial to gather responses for the model, the questions for the AHP pairwise-comparison assume the independence and lack of correlation of criteria and might be quite complex for responders. Second, the MCDA process has been shown from several studies that it is not fully adopted by the HTA community because of its methodological complexity. This is because several HTA committees might not be familiar with the full methodological concepts, tools, and data analyses steps, specially using the AHP model. This would explain some of the limited quality of evidence gathering from the scoping review, where most of the studies found used theoretical qualitative methodologies to explore criteria for technology adoption. Third, during the data collection and gathering stages, there were some missing responses from some experts. This might slightly affect the final geometric mean of the relative weights in the domain prioritizations or the ranking of the sub-criteria using arithmetic mean. This could have been addressed by a sensitivity analysis to understand the variation in the weights with changes in responses. However, the missing responses were from a very few numbers of comparisons, which would not have had a significant impact on the final results of the collective responses from all experts. Finally, there is a tendency for experts’ preferences to change over time with the change of their positions and duties and thus, their priorities might not represent their responses in their former positions used in this study.

CHAPTER 7: CONCLUSION AND SUMMARY

To date, Canada lacks a universal framework for weighted criteria elicitation for the early adoption of innovative new surgical technologies This is the first study that also includes a surgeon's perspective in the process of priority criteria elicitation.

In this MCDA study, we found that clinical outcomes are the most important criteria for both surgeons and non-surgeons that would influence their decisions to adopt a new surgical technology into the Canadian healthcare system. We also found that policies and procedures are considered the least important criteria for experts and decision makers. Despite publications and reports on HTA using CEA to favor which technologies to be adopted, the focus on endogenous costs undermines the value of CEA and impacts on the public. Surgeons and decision makers tend to use similar criteria without any order to adopt decisions. This study provides weighted prioritized criteria and sub-criteria that can be used in Canada to guide informed decision-making for early surgical technology adoption. Using different criteria for priority setting reflects how the MCDA can be utilized for experts from different backgrounds. Hospital value committees should also engage more surgeons in their committees because of surgeons' depth of understanding of the technologies and the added value of real-life experience and impact of these technologies on patients' health. More research is needed for countries with different socioeconomic and geopolitical systems that would have different priority criteria or weighting. This study also concludes that streamlined collaboration of all stakeholders, and inclusive of surgeons in technology appraisal committees, can generate an advantage for the early adoption of surgical technologies when clinical evidence is limited. The results and findings from this study pave the way for a trial to implement these weighted and prioritized criteria in a hospital setting for piloting and testing.

TABLES

Table 1: The 1-9 Saaty Scale for AHP preferences

Intensity of importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Judgment slightly favors one over another
5	Strong importance	Judgment strongly favors one over another
7	Very strong importance	A criterion is strongly favored, and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Intermediate values	Used to represent compromise between the priorities listed above

Table 2: The Random index table based on factors (domains)

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48

N: Number of Domains

RI: Random Index

***(Since we had 7 domains, we used RI of 1.32)**

Table 3: Pairwise comparison matrix (Criteria comparison matric "C") - ALL EXPERTS

		C1	C2	C3	C4	C5	C6	C7
	Step 1. Pairwise comparison matrix (Criteria comparison matric "C") - ALL EXPERTS							
		Economic	**Hospital specific**	**Technology specific**	**Patients' / public relevance**	**Clinical outcomes**	**Policies and procedures**	**Physician specific**
R1	**Economic**	1	0.995	0.681	0.682	0.188	1.078	0.975
R2	**Hospital specific**	1.005	1	1.265	0.688	0.210	1.413	1.290
R3	**Technology specific**	1.469	0.790	1	0.544	0.200	1.449	0.986
R4	**Patients/public relevance**	1.466	1.453	1.837	1	0.320	1.641	1.396
R5	**Clinical outcomes**	5.313	4.772	5.000	3.128	1	5.018	4.862
R6	**Policies and procedures**	0.928	0.708	0.690	0.609	0.199	1	0.869
R7	**Physician specific**	1.026	0.775	1.014	0.716	0.206	1.151	1
	SUM Columns	**12.207**	**10.494**	**11.488**	**7.368**	**2.322**	**12.750**	**11.378**

Table 4: Normalized matrix scores (Each cell divided by the sum of its column)

Step 2. Normalized matrix scores (Each cell divided by the sum of its column)							
	Economic	**Hospital specific**	**Technology specific**	**Patients' / public relevance**	**Clinical outcomes**	**Policies and procedures**	**Physician specific**
Economic	0.082	0.095	0.059	0.093	0.081	0.085	0.086
Hospital specific	0.082	0.095	0.110	0.093	0.090	0.111	0.113
Technology specific	0.120	0.075	0.087	0.074	0.086	0.114	0.087
Patients/public relevance	0.120	0.139	0.160	0.136	0.138	0.129	0.123
Clinical outcomes	0.435	0.455	0.435	0.425	0.431	0.394	0.427
Policies and procedures	0.076	0.067	0.060	0.083	0.086	0.078	0.076
Physician specific	0.084	0.074	0.088	0.097	0.089	0.090	0.088

Table 5: Normalized matrix scores with criteria weights (W) (The arithmetic average of each row)

Step 3. Normalized matrix scores with criteria weights (W) (The arithmetic average of each row)								
	Economic	**Hospital specific**	**Technology specific**	**Patients' / public relevance**	**Clinical outcomes**	**Policies and procedures**	**Physician specific**	**Weights**
Economic	0.082	0.095	0.059	0.093	0.081	0.085	0.086	0.083
Hospital specific	0.082	0.095	0.110	0.093	0.090	0.111	0.113	0.099
Technology specific	0.120	0.075	0.087	0.074	0.086	0.114	0.087	0.092
Patients/public relevance	0.120	0.139	0.160	0.136	0.138	0.129	0.123	0.135
Clinical outcomes	0.435	0.455	0.435	0.425	0.431	0.394	0.427	0.429
Policies and procedures	0.076	0.067	0.060	0.083	0.086	0.078	0.076	0.075
Physician specific	0.084	0.074	0.088	0.097	0.089	0.090	0.088	0.087

Table 6: PW comparison matrix with weighted sums (WS) (Multiplying each cell in step 1 'PW' by the Weights "W" table 3, then adding the weight row

Step 4. PW comparison matrix with weighted sums (WS) (Multiplying each cell in step 1 'PW' by the Weights "W" table 3, then adding the row								
	Economic	**Hospital specific**	**Technology specific**	**Patients' / public relevance**	**Clinical outcomes**	**Policies and procedures**	**Physician specific**	**Weighted Sum Values (WS)**
WEIGHT	**0.083**	**0.099**	**0.092**	**0.135**	**0.429**	**0.075**	**0.087**	
Economic	0.083	0.099	0.063	0.092	0.081	0.081	0.085	0.583
Hospital specific	0.083	0.099	0.116	0.093	0.090	0.106	0.112	0.700
Technology specific	0.122	0.079	0.092	0.073	0.086	0.109	0.086	0.646
Patients/public relevance	0.121	0.144	0.169	0.135	0.137	0.124	0.122	0.952
Clinical outcomes	0.440	0.474	0.459	0.422	0.429	0.378	0.424	3.025
Policies and procedures	0.077	0.070	0.063	0.082	0.085	0.075	0.076	0.529
Physician specific	0.085	0.077	0.093	0.097	0.088	0.087	0.087	0.614

Table 7: Checking for consistency and calculating Lambda

Step 5. Checking for consistency and calculating Lambda											
	Economic	**Hospital specific**	**Technology specific**	**Patients' / public relevance**	**Clinical outcomes**	**Policies and procedures**	**Physician specific**	**Weighted Sum Values (WS)**	**Weights (W)**	**Lambda "λ" (WS/W)**	**LAMBDA MAX "λ-Max"**
WEIGHT											
Economic	0.083	0.099	0.063	0.092	0.081	0.081	0.085	0.583	0.083	7.038	
Hospital specific	0.083	0.099	0.116	0.093	0.090	0.106	0.112	0.700	0.099	7.046	
Technology specific	0.122	0.079	0.092	0.073	0.086	0.109	0.086	0.646	0.092	7.034	
Patients/public relevance	0.121	0.144	0.169	0.135	0.137	0.124	0.122	0.952	0.135	7.062	
Clinical outcomes	0.440	0.474	0.459	0.422	0.429	0.378	0.424	3.025	0.429	7.056	
Policies and procedures	0.077	0.070	0.063	0.082	0.085	0.075	0.076	0.529	0.075	7.031	
Physician specific	0.085	0.077	0.093	0.097	0.088	0.087	0.087	0.614	0.087	7.040	
											7.044

Table 8: ANOVA Single factor. Assessment of statistical significance in responses from all expert groups for the weight prioritization of the 7 domains

a) Summary table

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
33 Experts Priority Vector	7	1	0.142857143	0.016293
Surgeons Priority vector	7	1	0.143142857	0.016032
Non-surgeons Priority vector	7	1	0.142857143	0.002956

b) ANOVA Output table

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.81E-07	2	1.90476E-07	1.62E-05	0.999983804	3.554557
Within Groups	0.211689	18	0.011760499			
Total	0.211689	20				

Table 9: ANOVA Single factor. Assessment of statistical significance in responses from all expert groups for the ranking prioritization of the 44 sub-criteria

a) Summary table

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Surgeons Priority vector	44	175.8093	3.995666221	0.323266
Non-surgeons Priority vector	44	176.2042	4.004640152	0.337803
33 Experts Priority Vector	44	175.7163	3.99355172	0.285537

b) ANOVA Output table

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.00305	2	0.00152501	0.004833	0.995178752	3.066391
Within Groups	40.70404	129	0.315535186			
Total	40.70709	131				

FIGURES

Figure 1: Technology adoption life cycle (adoption curve)

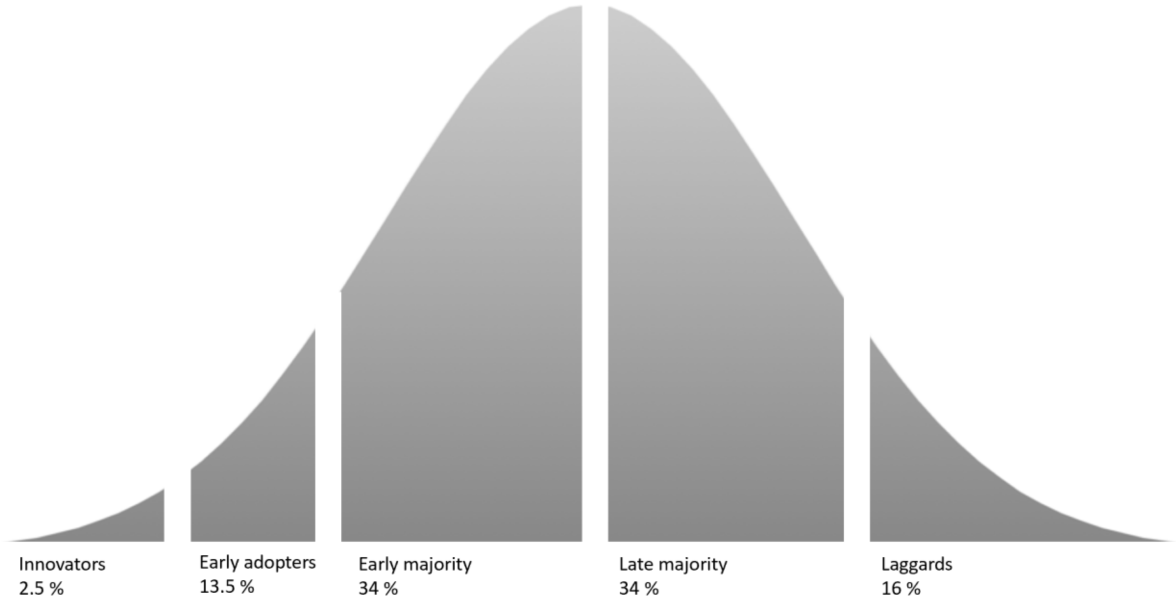
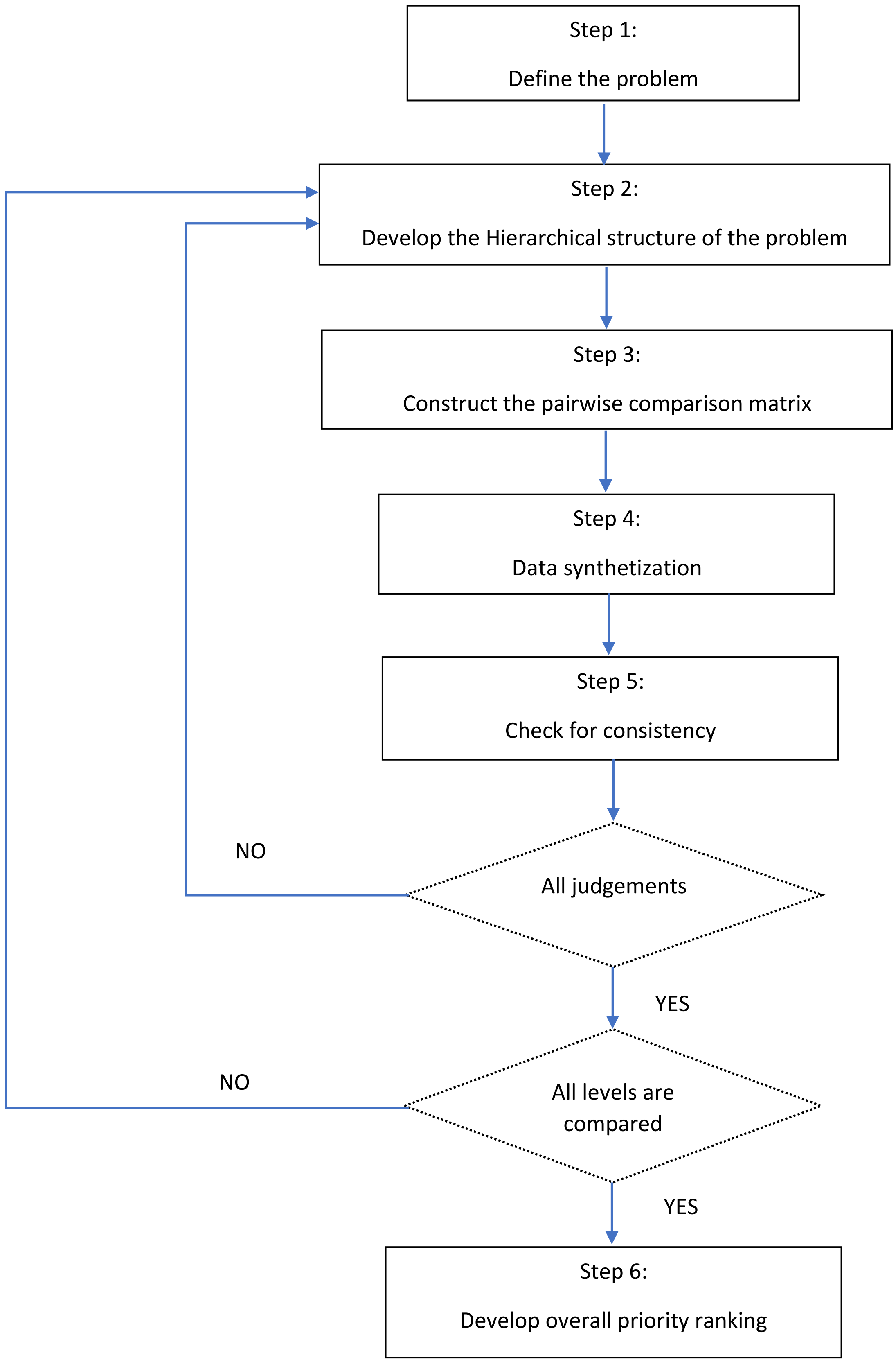


Figure 2: Flowchart diagram of the AHP method



ANNEXES

Annex 1:
Questionnaire 1 - criteria for adoption of surgical technologies into the Canadian healthcare system

Dear Doctor,

My name is Haitham Shoman, MD, MPH. I am a PhD at McGill University supervised by Dr Michael Tanzer. I am a Vanier Scholar being funded by the CIHR.

Dr Tanzer and I are researching the most pertinent and suitable priority criteria for decision-making in the early adoption of new surgical technologies into the Canadian healthcare system. As important and experienced leaders involved in technology adoption and/or assessment, we would be grateful if you could provide your insight into this important issue.

Below is a list of criteria that surgeons use for decision-making for the purchase and adoption of new surgical technologies that we have found after a comprehensive literature review. These criteria are not listed in any order nor prioritized. We are specifically interested in decision-making to purchase/adopt new technologies in the early adoption phase, before it is commonly used and long-term outcomes are known.

We would very much appreciate it if you review the criteria and let us know if there are any other criteria that you think we should add to this list. If you have any comments, please feel free to type them in. This first questionnaire will be used to help us develop the second questionnaire in which we will ask you to list the order of priority of the criteria from your perspective and experience.

Your input would be extremely appreciated for this research and will help us develop a future policy recommendation for the adoption of early technology in surgery.

Thank you in advance for your input in this important issue. I look forward to receiving your responses.

……………………………………………….

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CATEGORY 1: ECONOMIC	
Category	**Criteria**
Economic	
Any additional criteria?	
Any comments?	

CATEGORY 2: HOSPITAL SPECIFIC	
Category	**Criteria**
Hospital specific	
Any additional criteria?	
Any comments?	

CATEGORY 3: TECHNOLOGY SPECIFIC	
Category	**Criteria**
Technology specific	
Any additional criteria?	
Any comments?	

CATEGORY 4: PATIENTS' PUBLIC RELEVANCE	
Category	**Criteria**
Patients and public	
Any additional criteria?	
Any comments?	

CATEGORY 5: CLINICAL OUTCOMES	
Category	**Criteria**
Clinical outcomes	
Any additional criteria?	
Any comments?	

CATEGORY 6: POLICIES AND PROCEDURES	
Category	**Criteria**
Policies and procedures	
Any additional criteria?	
Any comments?	

CATEGORY 7: PHYSICIAN SPECIFIC	
Category	**Criteria**
Physician specific	
Any additional criteria?	
Any comments?	

Any additional comments, categories, and criteria you think are important, please list them below.

Annex 2: Questionnaire 2 for sub-criteria-ranking and criteria categories (domains) prioritization

Study Title:

Priority criteria setting for decision-making for the purchase and adoption of new surgical innovations into the Canadian Healthcare System.

Description:

Below is a list of currently used criteria for the adoption of surgical technologies in hospitals. They are in no specific order. We are interested in the criteria that you feel are important in the decision to purchase and adopt a **new surgical technology in the early adoption phase – ie. early on after its release and before the technology is commonly used**. Your input will help us in weighing which criteria are considered a priority, so as to aid surgeons, administrators and government agencies in their decisions regarding adopting a new surgical technology.

Instructions:

Kindly fill the below tables by checking the appropriate box.

Estimated time: 12 minutes.

Demographic data (*Please type in your name and click on the relevant box to check it***):**

Name	
Highest level of Education	☐ MD or equivalent (eg: BSc, BA)
	☐ Masters
	☐ PhD
Years of experience in your profession (cumulative)	☐ < 10 years
	☐ 11 – 20 years
	☐ 21 – 30 years
	☐ > 30 years

Survey Question 1:

Using the 5-point Likert scale, please check by clicking in the box that indicates the level of importance that you put on each of the following 7 criteria categories and their sub-criteria when deciding to purchase and adopt a new surgical technology in its early adoption phase.

CRITERIA	1 (Irrelevant)	2 (Less important)	3 (Neutral)	4 (Average importance)	5 (Absolute importance)
1- ECONOMIC	☐	☐	☐	☐	☐
1.1- Cost	☐	☐	☐	☐	☐
1.2 – Economic impact	☐	☐	☐	☐	☐
1.3- Cost effectiveness	☐	☐	☐	☐	☐
1.4- Depreciation cost	☐	☐	☐	☐	☐
2- HOSPITAL SPECIFIC	☐	☐	☐	☐	☐
2.1- Feasibility of implementation	☐	☐	☐	☐	☐
2.2- Structural / management support	☐	☐	☐	☐	☐
2.3- Strategic fit	☐	☐	☐	☐	☐
2.4- Relevance	☐	☐	☐	☐	☐
2.5- Standards of care	☐	☐	☐	☐	☐
2.6- Service coordination	☐	☐	☐	☐	☐
2.7- Being an academic and clinical center for excellence	☐	☐	☐	☐	☐

3- TECHNOLOGY SPECIFIC	☐	☐	☐	☐	☐
3.1- Technology simplicity	☐	☐	☐	☐	☐
3.2- Innovation	☐	☐	☐	☐	☐
3.3- Quality	☐	☐	☐	☐	☐
3.4- Real time feedback	☐	☐	☐	☐	☐
3.5- Efficiency	☐	☐	☐	☐	☐
CRITERIA	**1 (Irrelevant)**	**2 (Less important)**	**3 (Neutral)**	**4 (Average importance)**	**5 (Absolute importance)**
3.6- Maintenance availability	☐	☐	☐	☐	☐
3.7- Available evidence (quality)	☐	☐	☐	☐	☐
3.8- Alternatives available	☐	☐	☐	☐	☐
4- PATIENTS' / PUBLIC RELEVANCE	☐	☐	☐	☐	☐
4.1- Population health impact	☐	☐	☐	☐	☐
4.2- Human responses / patient experience	☐	☐	☐	☐	☐
4.3- Publicity and awareness	☐	☐	☐	☐	☐
4.4- Access	☐	☐	☐	☐	☐
4.5- Social and demographic	☐	☐	☐	☐	☐
5- CLINICAL OUTCOMES	☐	☐	☐	☐	☐
5.1- Safety	☐	☐	☐	☐	☐

5.2- Efficacy	☐	☐	☐	☐	☐
5.3- Effectiveness	☐	☐	☐	☐	☐
5.4- Prevention of adverse effects	☐	☐	☐	☐	☐
5.5-Evidence of peer reviewed assessments	☐	☐	☐	☐	☐
5.6- Disease burden	☐	☐	☐	☐	☐
6- POLICIES AND PROCEDURES	☐	☐	☐	☐	☐
6.1- Ethical	☐	☐	☐	☐	☐
6.2- Legislative	☐	☐	☐	☐	☐
6.3- Environmental	☐	☐	☐	☐	☐
6.4- Sustainability	☐	☐	☐	☐	☐
6.5- Political	☐	☐	☐	☐	☐
6.6- Appeals	☐	☐	☐	☐	☐
CRITERIA	**1 (Irrelevant)**	**2 (Less important)**	**3 (Neutral)**	**4 (Average importance)**	**5 (Absolute importance)**
6.7- Enforcement	☐	☐	☐	☐	☐
6.8- Certification of technology (Health Canada – ISO)	☐	☐	☐	☐	☐
7- PHYSICIAN SPECIFIC	☐	☐	☐	☐	☐
7.1- Sense of security	☐	☐	☐	☐	☐

7.2- Flexibility of usage	☐	☐	☐	☐	☐
7.3- Innovation champions	☐	☐	☐	☐	☐
7.4- Training	☐	☐	☐	☐	☐
7.5- Percentage of utilization	☐	☐	☐	☐	☐
7.6- Availability of the technology	☐	☐	☐	☐	☐

Survey Question 2:

For each line below, compare criteria A vs criteria B. Please determine which criteria (criteria A vs criteria B) is more important and rate them using 1-9 by checking the box.

E.g.: I believe the **shape** of the technology is *absolutely* *more important* than its **color** in influencing my decision. → Check box under number 9 closer to the **Criteria shape.**

The criteria are defined by the same sub-criteria that are listed in Question 1.

MAIN CATEGORIES																		
Criteria A									**EQUAL**									**Criteria B**
	9 Absolute importance	8	7 Very strong importance	6	5 Strong importance	4	3 Moderate importance	2	1 Equal importance	2	3 Moderate importance	4	5 Strong importance	6	7 Very strong importance	8	9 Absolute importance	
Color	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☒	Shape
Economic	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Hospital specific
Economic	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technology specific
Economic	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Patients' / public relevance
Economic	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Clinical outcomes
Economic	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policies and

																		procedur es
Criteria A	**9 Absolute importan ce**	**8**	**7 Very strong importan ce**	**6**	**5 Strong importan ce**	**4**	**3 Moderate importan ce**	**2**	**1 Equal importan ce**	**2**	**3 Moderate importan ce**	**4**	**5 Strong importan ce**	**6**	**7 Very strong importan ce**	**8**	**9 Absolute importan ce**	**Criteria B**
Economic	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Physician specific
Hospital specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Technolo gy specific
Hospital specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Patients' / public relevance
Hospital specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Clinical outcomes
Hospital specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policies and procedur es
Hospital specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Physician specific
Technolo gy specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Patients' / public relevance
Technolo gy specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Clinical outcomes

Technology specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policies and procedures
Technology specific	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Physician specific
Patients' / public relevance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Clinical outcomes
Patients' / public relevance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policies and procedures
Patients' / public relevance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Physician specific
Clinical outcomes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Policies and procedures
Clinical outcomes	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Physician specific
Policies and procedures	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	Physician specific

Thank you for your time and expertise. It is very much appreciated!

**For any questions, contact: Haitham Shoman haitham.shoman@mail.mcgill.ca*

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