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Cost-effectiveness analysis of frailty assessment 1 in older patients undergoing coronary artery bypass grafting (CABG) surgery

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Abstract

Background: In perioperative settings, formal frailty assessment has been shown to reduce mortality. This study examined the cost-effectiveness associated with a frailty assessment initiative among patients aged 65 with coronary artery disease who are under consideration for CABG.

Methods: A combined decision tree and Markov model was developed to estimate costs and quality-adjusted life years (QALYs) over a 21-year time horizon. Clinical parameters were obtained from published literature. Utilities were derived from the published literature and Canadian Community Health Survey. Costs were obtained from the Ontario fee schedule and

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published literature. Sensitivity analysis and scenario analysis were conducted to assess the robustness of results. Expected value of perfect information (EVPI) analysis was conducted to estimate the expected value of further research.

Results: The frailty assessment initiative had a lower average cost per patient than no frailty assessment ($19,567 compared to $20,062). QALYs with frailty assessment were 6.82, which was 0.47 years more than with no frailty assessment. Frailty assessment was dominant compared to no frailty assessment. Results were robust to changes in the input parameters. Probabilistic sensitivity analysis showed frailty assessment was cost-effective. At a willingness to pay (WTP) threshold of $50,000/QALY, there was 100% probability of frailty assessment being cost-effective and the EVPI per patient was $0. Scenario and sensitivity analysis showed frailty screening remained cost-effective when changing the cohort average age, removing health benefits for non-frail patients and using subjective judgement to modify effectiveness parameters.

Conclusions: Frailty assessment may be good value for money. However, when considering the the Ontario health care system, and limited availability of geriatric consultation services, inadequate health system capacity may hinder full implementation of frailty assessment. Thus, the estimated benefits of frailty screening may not be achievable in practice.

INTRODUCTION

Coronary artery bypass grafting (CABG) is an operation to treat coronary artery disease, which is the most common type of heart disease.[1] Although the shift from CABG to percutaneous coronary intervention (PCI) has resulted in a decline in the overall number of CABG surgeries being performed, CABG remains the most common procedure in cardiac surgery today.[2] Currently, there are over 6,000 CABG operations performed annually in Ontario, Canada.[2] In contemporary clinical practice, patients referred for CABG tend to be older and have more comorbidities, which may be associated with postoperative complications, prolonged in-hospital length of stay and increased healthcare costs.[2,3]

There is a wide variation in the cost of performing CABG, and frailty has been recognized as a predictor of length of index hospitalization and post-operative costs.[3–5] Frailty is defined as a syndrome of impaired physiological reserve and increased vulnerability to stressors.[6,7] When exposed to stressors, such as chronic illness and surgery, frail patients are prone to adverse events, procedural complications, prolonged recovery, functional decline, and mortality.[6] In older adults undergoing cardiac surgery, the prevalence of frailty may be as high as 60%.[6]

Existing evidence demonstrates the predictive value of frailty in patients undergoing cardiac surgery. Frailty is associated with higher mortality at 6 months or later after major cardiac surgical procedures and minimally invasive cardiac surgical procedures.[8] Lee et al [9] suggest frailty is an independent predictor of in-hospital mortality, institutional discharge, and reduced survival amongst cardiac surgical patients. As frailty is associated with higher rates of perioperative mortality and healthcare costs[3,8,9], there is an opportunity to reduce the impact of frailty and associated hospital resource consumption by prospectively identifying frail patients and intervening to mitigate frailty-associated risks.

Although frailty assessment provides additional information not captured by traditional surgical risk assessment, few studies have examined the effectiveness of a frailty screening initiative for guiding surgical decision-making and improving outcomes.[6] To date, no study has examined the cost-effectiveness of frailty assessment in elderly patients undergoing CABG. Therefore, we conducted an economic evaluation to estimate the cost-effectiveness of frailty assessment among elderly patients undergoing CABG in Ontario, Canada.

METHODS

We developed an economic model to estimate the expected costs and quality-adjusted life years (QALYs) associated with frailty assessment compared with no frailty assessment for older patients (65+ years) who had two- or three-vessel coronary artery disease and were scheduled for elective CABG. Estimates of the effect of frailty screening were derived from the Omaha Frailty Screening Initiative (FSI), a quality improvement project aimed at improving postoperative survival at the Nebraska Western Iowa Veterans Affairs Medical Center (NWI VAMC).[10] Beginning July 1, 2010, all patients undergoing elective surgery at the NWI VAMC completed the Risk Analysis Index (RAI) of frailty.[10] Patients with RAI>=21 were flagged as potentially frail, and their surgical decision making was reviewed by an interdisciplinary team including representatives from surgery, anesthesiology, critical care and palliative care.[10] Using prospectively collected data from the Veterans Affairs Surgical Quality Improvement Program (VASQIP) registry, retrospective multivariable logistic regression analyses compared mortality rates before and after FSI implementation, controlling for age, frailty, and predicted mortality.[10] We incorporated parameter estimates from this study on the effect of frailty screening in CABG.

We compared frailty assessment prior to CABG (the intervention) with no frailty assessment (the current standard of care at cardiac centers). With no frailty assessment, we assumed patients would receive the usual perioperative risk assessment before CABG. For the option of frailty assessment, patients would receive frailty screening using the RAI administered by cardiac surgeons as per the FSI protocol.[10] After screening, non-frail patients would receive standard preoperative healthcare. If identified as frail, we assumed patients would be referred for a Comprehensive Geriatric Assessment (CGA), in addition to receiving regular preoperative healthcare. Amongst those patients confirmed as frail by CGA, the clinicians involved in the patient's care (surgeons, geriatricians, and anesthesiologists) would engage in communication aimed at identifying and mitigating frailty-associated risks. We assumed that some patients identified as frail would undergo PCI in avoidance of the increased perioperative risk of CABG surgery.[11]

We used the perspective of the Ontario Ministry of Health and Long-Term Care over a 21-year time horizon. All analyses were performed in TreeAge 2019 (19.2.0-v20190702).

Model Description

The economic evaluation model was composed of a simple decision tree modeling the first postoperative year and a Markov model for the subsequent 20 years (Figure 1). During the one-year postoperative phase, we modelled patient risk of death at 30, 180 and 365 days. We incorporated the expected cost of the index hospitalization, the cost from discharge to one year, and the cost of comprehensive geriatric consultation for patients identified as frail. Patients who survived the first year entered the Markov model, which consists of two health states: alive and dead. All costs and effects were calculated using the half-cycle correction. Both costs and effects were discounted using a rate of 1.5%, in accordance with the Canadian Agency for Drugs and Technologies in Health guidelines.[12]

Clinical Parameters

The parameters used for the economic model came from relevant studies on the costs and effects of frailty assessment in the literature (Table 1). The prevalence of frailty (23.34%) was estimated based on a study of Tran et al [13], which investigated the effects of frailty in patients undergoing isolated CABG in Ontario, Canada, from 2008 to 2015. The sensitivity (50%) and specificity (82.0%) of RAI of identifying frailty was obtained from Hall et al [14], which developed and validated the RAI for patients scheduled for non-cardiac surgery. In the absence of frailty assessment (standard of care), the probability of death after CABG was obtained from Tran et al [13]. Reduction in mortality associated with frailty assessment was estimated by multiplying this probability by risk ratios of death derived from the FSI study.[10] The probability of death after PCI was estimated by dividing the probability of death after CABG by risk ratios of death derived from the study by Weintraub et al [15], which compared the survival of PCI and CABG up to five years. Transition probabilities of death beyond year one after CABG were derived by extrapolating the risk-adjusted survival curve from the study by Tran et al[13] (Supplementary Table S1). Transition probabilities of death beyond year one after PCI were estimated by dividing the mortality after CABG by the risk ratios based on the study by Weintraub et al[15] (Supplementary Table S2).

Utility

We calculated QALYs by multiplying the length of time in a health state by the utility weight for that health state. Health utility estimates at 1, 2, 3, 4, and 5 years were derived from the study by Brandao et al[16], which evaluated the utility and QALYs for patients with coronary artery disease who underwent CABG, PCI or medical therapy. Health utility estimates beyond 5 years were obtained from the 2014 Canadian Community Health Survey by age group (Table 1), restricted to adults age 65 and older who responded yes to the question, “Do you have heart disease?” (Variable CCC_121).[17] We calculated the mean and variance of the Health Utilities Index Mark 3 (HUI3) using the Canadian Community Health Survey sample weights.

Cost

For patients undergoing CABG, the cost of index hospitalization was obtained from Goldfarb et al[3], a recent study that investigated the cost of cardiac surgery in frail versus non-frail elderly patients. The cost from discharge to one year and annual cost after year one were obtained from Lamy et al[18]. For patients undergoing PCI, the index hospitalization cost was obtained from the study by Wijeysundera et al.[19] The cost from discharge to one year was obtained from the study by Bagai et al[20]. After the first year, the average annual costs per patient who underwent PCI was obtained from Weintraub et al.[21] The average annual costs estimated post-operative hospitalization costs, physician fees, and costs of rehabilitation. For patients identified as frail by frailty screening, the cost of comprehensive geriatric assessment was obtained from the Ontario Health Insurance Plan Schedule of Benefits and Fees.[22] As it only took clinical staff less than 2 minutes to complete the RAI questionnaires, the frailty screening performed by surgeons was assumed to be incorporated into the process of perioperative risk assessment and to incur no extra costs from the perspective of the Ontario Ministry of Health and Long-Term Care.[14] All costs are expressed in 2019 Canadian dollars using purchasing power parities conversion.[23]

Analysis

Model Validation.—Survival rates generated by the Markov model were compared with the survival curve from the original study. (Supplementary Figure S1)

Base-Case Analysis.—The expected incremental costs, incremental effects, and incremental cost-effectiveness ratios (ICERs) were calculated.

Sensitivity Analyses.—Sensitivity analyses were conducted to assess the impact of uncertainty on the results. Specifically, one-way sensitivity analyses were conducted varying individual parameters within plausible ranges (Table 1). To assess the joint uncertainty of the input parameters, we performed a probabilistic sensitivity analysis with 10,000 independent simulations. Given concerns about the generalizability of the findings in the Hall study to our patient population, we used subjective judgements to adjust model parameters in order to reflect uncertainty.[24] Instead of using the point-estimates and 95% confidence interval for each of the relative risk parameters (30, 180 and 365-day mortality) we adjusted the estimates and distributions for bias and uncertainty. In the bias adjusted sensitivity analysis, we attenuated the mortality benefits by multiplying the original relative risk parameters from the Hall study by a factor of 2.5 (i.e. relative risk closer to 1). In this way we addressed potential bias from incorporating effectiveness estimates derived from a younger, general surgery population to an older cardiac surgical population. In the uncertainty adjusted sensitivity analysis, we inflated the variance of each relative risk parameter, in order to reflect concerns about uncertainty in the estimates derived from the Hall study. In both the bias and uncertainty adjusted analyses, we set the upper limit of the 95% confidence interval to 1, reflecting our judgement that the FSI is unlikely to increase mortality risk in the patient population. We calculated the lower limit of the 95% confidence interval based on the normal distribution of the relative risk on the log transformed scale. The original parameters and distributions and those modified using subjective judgement are provided in Supplemental Table S4a.

Scenario Analyses.—The Hall et al[10] study demonstrated benefits of frailty screening among both frail and non-frail patients. We performed a scenario analysis, assuming no benefits to non-frail patients by assigning a risk ratio of mortality due to frailty assessment of 1.0 to non-frail patients. We also performed scenario analyses adjusting the average age of the cohort of patients to 70, 75, and 80 years.

Expected value of perfect information (EVPI).—In theory, perfect information can eliminate the possibility of making a wrong decision about implementing frailty screening. The EVPI uses the results of the probabilistic sensitivity analysis to quantify the costs of imperfect information, calculated as the probability that frailty screening is not good value for money multiplied by the expected loss of wrongly implementing frailty screening when it's not good value for money. The EVPI is an upper limit estimate on the value of further research. If the EVPI exceeds the expected costs of additional research, then acquiring more information is desirable before implementing practice change.[25] We multiplied per-person EVPI by the annual number of CABG procedures in Ontario to estimate population EVPI.

RESULTS

Model validation.

Internal validation showed the survival after CABG generated by the Markov model fit the original survival curves well (Supplementary Figure S1).

Base-Case Result.

Over the 21-year time horizon, the expected costs of frailty assessment and no frailty assessment were $19,567 and $20,062, respectively. The expected QALYs were 6.82 and 6.35, respectively. Compared with no frailty assessment, the implementation of frailty assessment was estimated to produce 0.47 more QALYs and reduce costs by $495, suggesting frailty assessment was dominant (Table 2).

Sensitivity Analyses.

One-way sensitivity analysis showed the impact of individual parameters on the incremental cost-effectiveness ratio (Figure 2). Although the ICER varied the most with changes in the proportion of patients undergoing PCI instead of CABG due to frailty assessment (ICER increased as the probability increased), followed by the cost of index hospitalization for frail patients undergoing CABG (ICER decreased as the cost increased), results were robust in that the ICER did not exceed $50,000 per QALY. Two-way sensitivity analysis on the sensitivity and specificity of the RAI showed that within plausible ranges, no frailty assessment was dominated by frailty assessment (Supplementary Figure S2). Results of probabilistic sensitivity analyses show that the mean costs of frailty assessment and no frailty assessment were $19,941 and $19,381, respectively, resulting in frailty assessment being dominant. (Supplementary Table S3) The probability of frailty assessment being cost-effective was 100% at a willingness-to-pay (WTP) threshold of $50,000/QALY (Supplemental Figure 3). When we adjusted the relative risk parameters for bias, frailty assessment was cost-effective but no longer dominant, with an ICER of $508/QALY. We have included a supplemental table comparing the probabilistic sensitivity analysis adjusted for bias and uncertainty to the original results. (Supplemental Table S4b).

Scenario Analyses.

We removed the health benefits for non-frail patients. Because only frail patients achieve health benefits from frailty assessment, decreased health QALYs gained were observed for the frailty assessment strategy compared to the base-case (Supplementary Table S5). Decreased health QALYs gained were also observed when the age of the cohort of patients was 70, 75, and 80 years. (Supplementary Table S5)

Expected Value of Perfect Information (EVPI) Analyses.

At a WTP threshold of $50,000/QALY, the EVPI per patient was $0 (Supplemental Figure S3). This suggests frailty screening should be adopted immediately as further research has no value. When we adjusted the relative risk parameters for uncertainty, the EVPI increased to $0.008 per patient. The EVPI increased further to $2.96 per patient when relative risk parameters were adjusted for bias. Since approximately 6,000 CABG procedures are performed annually in Ontario, the population-level value of perfect information was estimated at $17,760 in the bias adjusted analysis. (Supplemental Table S4b) Further research to inform decision making about frailty screening should be considered if conducting research is less expensive than this threshold.

DISCUSSION

We examined the cost-effectiveness of a frailty assessment initiative among patients aged 65 and older scheduled to undergo elective CABG. We found that frailty assessment is a dominant strategy compared with no frailty assessment. Over a 21-year time horizon, our model demonstrates 0.47 incremental QALYs of frailty assessment, which mainly results from the reduced mortality rate within the first year after CABG. Our model suggests frailty assessment is associated with cost savings, mainly resulting from shifting a proportion of frail patients scheduled for CABG to PCI. The model results were robust to a range of sensitivity and scenario analyses, due to the relatively inexpensive cost of frailty screening and the assumption that frailty screening, followed by confirmatory comprehensive geriatric assessment, is associated with no harms.

As CorHealth Ontario showed in a recent report[2], patients referred for CABG now tend to be older with more comorbidities, resulting in increased complexity. Coronary artery represents an iatrogenic physiological stressor that may exceed frail patient’s physiologic reserve, leading to morbidity, mortality, functional decline, and prolonged recovery.[6] Existing evidence has demonstrated higher rates of mortality, longer length of hospital stay, and greater risk of institutionalization among frail patients who undergo cardiac surgery.[8,9] Preoperative evaluation of surgical risk using cardiac risk scores, such as the Society of Thoracic Surgeons Predicted Risk of Mortality (STS-PROM) and Euro SCORE, may not capture frailty and thus may not reflect the true ‘biological status’ of the patient.[26] The incorporation of frailty assessment into clinical practice for CABG surgical patients may provide important information about risk and prognosis, to assist with shared decision-making, and optimize patient outcomes.[27,28] To the best of our knowledge, this is the first study to estimate the cost-effectiveness of a frailty assessment initiative among patients scheduled for CABG.

The frailty screening initiative we considered featured two-step frailty assessment in which all patients would be screened using a rapid, user-friendly tool to screen out robust patients, and those flagged as potentially frail would be referred for CGA. This approach is consistent with the suggestion that simple low-cost frailty measurement should be used for screening and a second more intensive test used for a more comprehensive assessment.[30] We acknowledge that consensus has not yet emerged regarding the definition of frailty or its optimal measurement.[30] We therefore performed a two-way sensitivity analysis on sensitivity and specificity of frailty screening. The results demonstrate frailty assessment remains a dominant strategy at a willingness to pay threshold of $50,000 per QALY, suggesting that despite wide variation in diagnostic accuracy, the decision to implement a frailty assessment initiative would be good value for money.

The EVPI analyses suggest that if decision makers are willing to pay $50,000 per additional QALY, the frailty screening initiative should be adopted immediately, as additional research has little to no value. EVPI quantifies the benefit of eliminating all uncertainty in the decision to implement frailty screening and represents the upper limit on the value of further research.[25] If this research cannot be conducted at a cost lower than the EVPI, then future research has no value. For example, a cluster randomized trial of frailty screening in the 20 cardiac centres across Ontario could provide additional information on model parameters such as the effectiveness and cost of frailty screening, proportion of frail patients who undergo PCI rather than CABG and short-term mortality risk. However, the cost of such a trial would exceed the base case population EVPI of $0, as well as the bias adjusted EVPI estimate of $17,760.

Our study has several important limitations. Firstly, our analysis presumes no wait times for CGA. In some health care systems, specialist consult services are not readily available. Ageing populations and increased rates of surgery amongst older adults may increase demand, putting increased strains on the supply of geriatric services in the future. Waiting for CGA with untreated coronary artery disease may not be desirable for the patient, may increase the risk of harm and may invalidate the estimated health benefits from the model. It is unclear to what extent non-specialist geriatric services can serve as a substitute. Second, we conceptualized the benefits of frailty screening as enhancing decision making by the patient and clinical team, prompting review and optimization of perioperative plans, that in response to a frailty diagnosis, may change the decision to operate or change other aspects of perioperative management.[10] Researchers are evaluating pre-habilitation or nutritional interventions to reduce frailty.[31,32] We are not aware of these interventions being tested preoperatively for their usefulness in improving health outcomes, but in theory, these would have the potential to improve health outcomes but also to delay surgical intervention and increase the cost of screening. Third, frailty screening, which can be completed in less than 2 minutes, and perioperative optimization were assumed to be incorporated into care at no extra cost to the Ontario Ministry of Health and Long-Term Care. In practice, cardiac centres may incur an opportunity cost that is not reflected in the model. Although additional interventions and opportunity costs were not conceptualized in our model, model results were robust to varying the average cost of screening over a wide range. Fourth, our study did not include societal costs which may provide a more comprehensive estimate of the cost-effectiveness of frailty assessment, as frail patients may require more caregiver support or social services following CABG.[33] Fifth, in the absence of studies evaluating frailty screening in older adults undergoing CABG, we relied on the FSI study, in which a population of mean age 60.3 years underwent elective non-cardiac surgery.[10] Although we have based our analysis on estimates of long-term mortality in frail and non-frail patients undergoing CABG and applied the relative risk of death derived from the FSI study, to these mortality estimates, concerns about the generalizability of the findings remain. Furthermore, in the absence of randomized controlled trials or comparative cohort studies, estimates may be subject to biases or confounding.[10] However, our results were robust to a series of sensitivity analyses designed to address concerns about the generalizability of the effectiveness data. Finally, our model only considered the impact of frailty assessment on mortality and did not explicitly model an effect on other clinical outcomes such as readmission, stroke, and major bleeding.

CONCLUSION

When considering cardiac procedures for patients, clinical practice guidelines recommend assessing frailty as one component of risk. Using a health economic model, our study suggests that a frailty assessment initiative may lead to improved survival after CABG, with reduced healthcare costs, in settings with immediate availability of geriatric consultation. In these settings, frailty screening is good value for money and further research is likely unnecessary. Inadequate health system capacity to implement frailty screening, in particular limited access to geriatrician health services, means translation of our research findings to clinical practice should be cautious.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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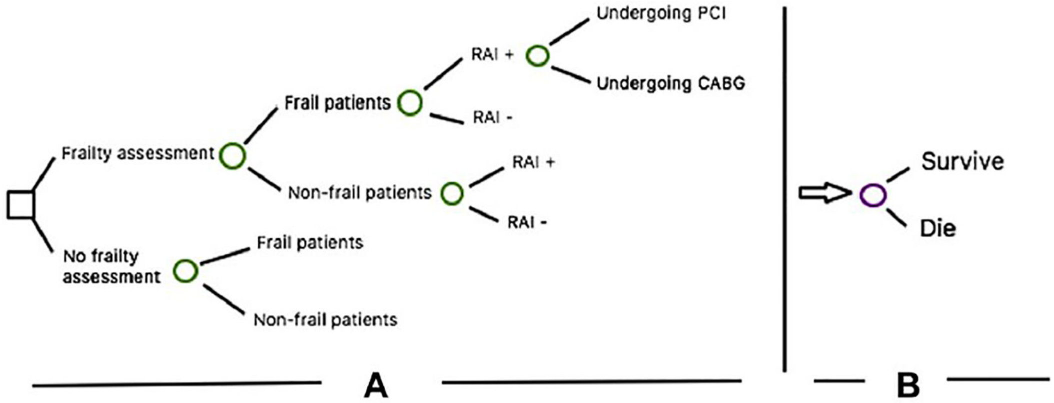

Figure 1.

Model structure: A simple decision tree for the first postoperative year (**A**) followed by a Markov model for the subsequent 20 years (**B**). In the frailty-assessment strategy, patients receive frailty assessment measured using the RAI and are deemed frail (RAI+) or not frail (RAI−). Patients deemed RAI+ are referred for comprehensive geriatric assessment and then undergo either PCI or CABG. We only considered the possibility of undergoing PCI in patients identified as frail. We modelled the probability of death at 30, 180, and 365 days postoperatively and every year thereafter. Patients who survive the first year enter the Markov model, which consists of 2 health states: alive and dead. CABG, coronary artery bypass grafting; PCI, percutaneous coronary intervention; RAI, Risk Analysis Index.

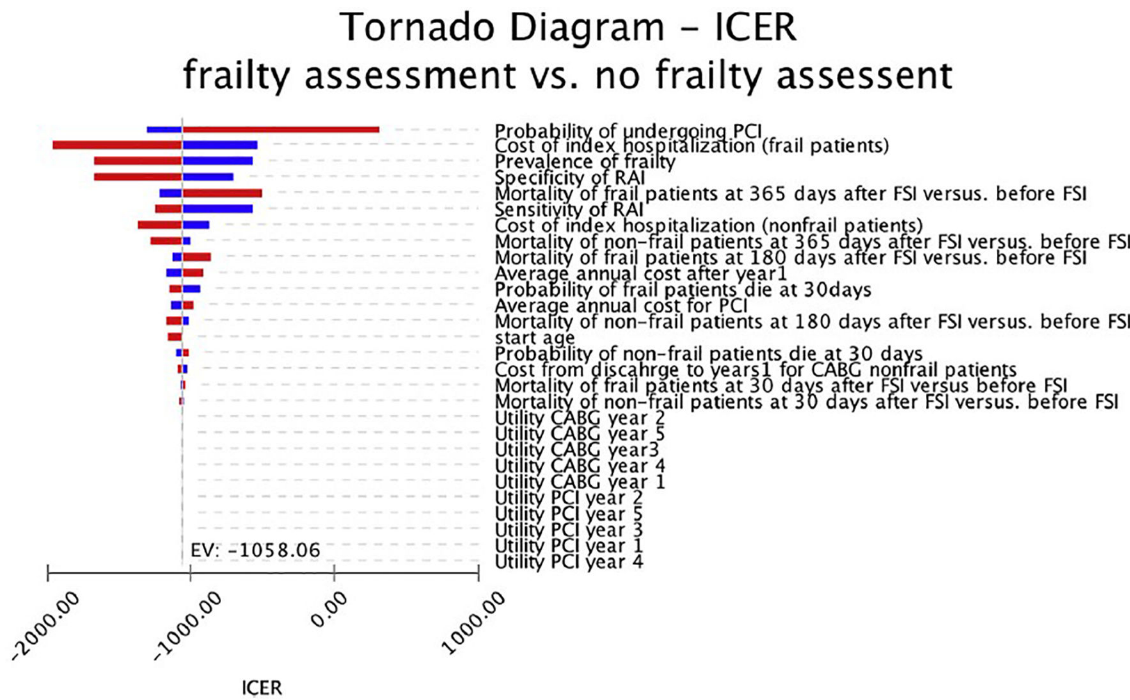

Figure 2.

Tornado diagram of 1-way sensitivity analyses showing the impact of changes in individual input parameters on the incremental cost-effectiveness ratio (ICER) of the frailty-assessment initiative compared with no frailty assessment. Parameter values are ordered from those associated with the largest changes in the ICER to those associated with the smallest changes. CABG, coronary artery bypass grafting; EV, expected value; PCI, percutaneous coronary intervention; RAI, Risk Analysis Index.

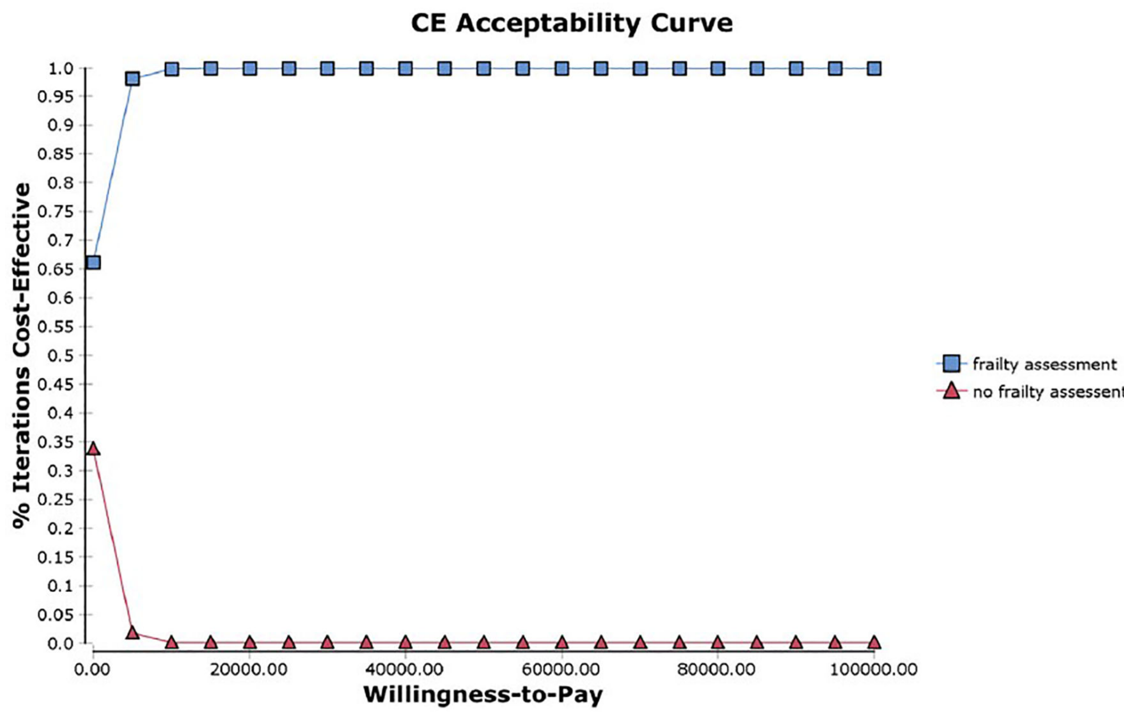

Figure 3.
Cost-effectiveness acceptability curve for frailty assessment vs no frailty assessment. Results of the probabilistic analysis are shown in the plot as the percentage of iterations in which the incremental cost-effectiveness ratio (ICER) fell below the willingness-to-pay threshold, with the threshold ranging from $0 to $100,000 per Quality-Adjusted Life Year (QALY). Probabilities were determined by 10,000 independent simulations in which inputs were selected randomly from the distributions described in Table 1. CE, cost effectiveness.

Table 1.

Parameters and sources

Model variables	Value	*95% CI (unless otherwise indicated)	Distribution (Parameters)	Reference
Prevalence of frailty	0.2334	0 – 1 (all possible values)	Beta (α=5,241, β=17,217)	Tran et al[13]
Sensitivity of RAI	0.50	0 – 1 (all possible values)	Beta (α=511, β=510)	Hall et al[14]
Specificity of RAI	0.82	0 – 1 (all possible values)	Beta (α=837, β=184)	Hall et al[14]
Patients undergoing CABG				
Probability non-frail patients die at 30 days	0.0204	0.0163 – 0.0245 (±20% in base value)	Beta (α=351, β=16,866)	Tran et al[13]
Probability non-frail patients die at 180 days	0.1163[a]			
Probability non-frail patients die at 365 days	0.2191[b]			
Probability frail patients die at 30 days	0.0256	0.0205 – 0.0307 (±20% in base value)	Beta (α=134, α=5,107)	Tran et al[13]
Probability frail patients die at 180 days	0.1441[a]			
Probability frail patients die at 365 days	0.2674[b]			
Relative risk of CABG as compared with PCI				
Relative risk of death at 30 days	1.72	1.52 – 1.89	Log normal (μ=0.542324, s=0.048088)	Weintraub et al[15]
Relative risk of death at 365 days	0.95	0.90 – 1.00	Log normal (μ=−0.051293, s=0.026170)	Weintraub et al[15]
Patients undergoing PCI				
Probability patients referred to CABG undergo PCI	0.05	0 – 0.28 (values obtained from literature)		Tu et al[11]
Probability frail patients die at 30 days	0.0149[c]			
Probability frail patients die at 180 days	0.1524[d]			
Probability frail patients die at 365 days	0.2815[c]			
Risk ratio of death				
Mortality of frail patients at 30 days after FSI compared to before FSI	0.3115	0.0970 – 1	Log normal (μ=−1.16636, s=0.59508)	Hall et al[10]
Mortality of frail patients at 180 days after FSI compared to before FSI	0.3222	0.1038 – 1	Log normal (μ=−1.13258, s=0.577848)	Hall et al[10]

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Model variables	Value	*95% CI (unless otherwise indicated)	Distribution (Parameters)	Reference
Mortality of frail patients at 365 days after FSI compared to before FSI	0.3391	0.1150 – 1	Log normal (μ=−1.08146, s=0.551765)	Hall et al[10]
Mortality of non-frail patients at 30 days after FSI compared to before FSI	0.25	0.0625 – 1	Log normal (μ=−1.38629, s=0.707293)	Hall et al[10]
Mortality of non-frail patients at 180 days after FSI compared to before FSI	0.3429	0.1176 – 1	Log normal (μ=−1.07032, s=0.54608)	Hall et al[10]
Mortality of non-frail patients at 365 days after FSI compared to before FSI	0.34	0.1156 – 1	Log normal (μ=−1.07881, s=0.550413)	Hall et al[10]
Cost Items				
Comprehensive geriatric assessment	300.70			OHIP A775[22]
Index hospitalization (frail patients undergoing CABG)	30,865 [e]	21,937–46,403 (interquartile range)	Gamma (α=1, λ=0.0000324)	Goldfarb et al [3]
Index hospitalization (non-frail patients undergoing CABG)	22,122 [e]	18,844–27,799 (interquartile range)	Gamma (α=1, λ=0.0000452)	Goldfarb et al [3]
Ratio of cost for frail patients to cost for non-frail patients	2.02 [f]	1.60–2.45 (interquartile range)		Derived from Goldfarb et al[3]
Index hospitalization (non-frail patients undergoing PCI)	10,764	281.6–19,864 (values obtained from literature)	Gamma (α=1, λ=0.0000929)	Wijeysundera et al[19]
Index hospitalization (frail patients undergoing PCI)	21,743[g]			
The cost from discharge to one year (non-frail patients undergoing PCI)	2,158	1,243–3,753	Gamma (α=1, λ=0.0004634)	Bagai et al[20]
The cost from discharge to one year (frail patients undergoing PCI)	4,359[h]			
The cost from discharge to one year (non-frail patients undergoing CABG)	1,681	1,455–1,961	Gamma (α=1, λ=0.0005949)	Lamy et al[18]
The cost from discharge to one year (frail patients undergoing CABG)	3,975[i]			
Average annual cost year two and beyond for patients undergoing CABG	1,271	1,183–1,379	Gamma (α=1, λ=0.0007868)	Lamy et al[18]
Average annual cost year two and beyond for patients undergoing PCI	5,193	4,154–6,232 (±20% in base value)	Gamma (α=1, λ=0.0001926)	Weintraub et al[21]
Utility				
1 year after CABG	0.774[e]	0.761–0.809	Beta (α=4.1990, β=1.2261)	Brandao et al[16]
2 years after CABG	0.785[e]	0.762–0.809	Beta (α=3.2591, β=0.8926)	Brandao et al[16]
3 years after CABG	0.803[e]	0.771–0.812	Beta (α=2.1331, β=0.5233)	Brandao et al[16]
4 years after CABG	0.794[e]	0.770–0.809	Beta (α=1.4987, β=0.3888)	Brandao et al[16]
5 years after CABG	0.780[e]	0.761–0.809	Beta (α=0.9644, β=0.2720)	Brandao et al[16]

Model variables	Value	*95% CI (unless otherwise indicated)	Distribution (Parameters)	Reference
1 year after PCI	0.808[e]	0.761–0.816	Beta (α=2.8152, β=0.6690)	Brandao et al[16]
2 years after PCI	0.798[e]	0.769–0.809	Beta (α=2.2333, β=0.5653)	Brandao et al[16]
3 years after PCI	0.809[e]	0.793–0.828	Beta (α=2.0804, β=0.4912)	Brandao et al[16]
4 years after PCI	0.809[e]	0.788–0.821	Beta (α=1.3433, β=0.3171)	Brandao et al[16]
5 years after PCI	0.809[e]	0.794–0.842	Beta (α=0.7193, β=0.1698)	Brandao et al[16]
Patients aged 70 to 74	0.77			CCHS[17]
Patients aged 75 to 79	0.71			CCHS[17]
Patients aged 80 or older	0.60			CCHS[17]

*: Values used in one-way sensitivity analysis

a: P_180days=1-Exp [6*ln (1-P_30days)]

b: P_365days=1-Exp [12*ln (1-P_30days)]

c: Probability of death (frail patients undergoing PCI)= Probability of death (frail patients undergoing CABG)/Relative risk of death (CABG as compared with PCI)

d: P_180days = 1− Exp [1/2 *ln (1-P_365days)]

e: Data are presented as median

f: Based on the cost estimates by Goldfarb and colleagues,[3] the ratio of cost for frail patients to cost for non-frail patients = $\frac{\text{Index hospitalization (frail patients undergoing CABG)}}{\text{Index hospitalization (non} - \text{frail patients undergoing CABG)}}$

g: Index hospitalization costs for frail patients undergoing PCI = Index hospitalization costs for non-frail patients undergoing PCI*Ratio of cost for frail patients to cost for non-frail patients

h: The cost from discharge to one year (frail patients undergoing PCI)=The cost from discharge to one year (non-frail patients undergoing PCI) * Ratio of cost for frail patients to cost for non-frail patients

i: The cost from discharge to one year (frail patients undergoing CABG)=The cost from discharge to one year (non-frail patients undergoing CABG) * Ratio of cost for frail patients to cost for non-frail patients

All cost values are adjusted for inflation to 2019 Canadian dollars using the Bank of Canada Consumer Price Index (https://www.bankofcanada.ca/rates/related/inflation-calculator/) and the Purchasing Power Parities (https://www150.statcan.gc.ca/n1/daily-quotidien/180424/cg-b001-eng.htm). RAI, Risk Analysis Index; FSI, Frailty Screening Initiative; CABG, Coronary Artery Bypass Grafting; PCI, Percutaneous Coronary Intervention; OHIP, Ontario Health Insurance Benefit Schedule of Benefit; CCHS, Canadian Community Health Survey.

Distribution parameters: α, β, μ s, λ.

https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1410030701 Statistics Canada

Table 2.

Results of base-case analysis

Strategy	Cost	Incremental Cost	QALYs	Incremental QALYs	ICER
No frailty assessment	$20,062		6.35		
Frailty assessment	$19,567	($495)	6.82	0.47	dominant

QALYs, Quality-adjusted life-years; *ICER*, incremental cost-effectiveness ratio. Costs are reported in 2019 Canadian dollars.