Influence of Intraoperative Conversion From Off-Pump to On-Pump Coronary Artery Bypass Grafting on Costs and Quality of Life: A Cost-Effectiveness Analysis

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Objective: **Off-pump coronary artery bypass (OPCAB) surgery has become a widely accepted alternative to standard coronary artery bypass graft (CABG) surgery using cardiopulmonary bypass; however, the influence of intraoperative conversion from OPCAB to standard CABG on costs and quality of life is unclear. The objective of this study was to determine whether intraoperative conversion affects costs and quality of life.**

Design: **A decision-analysis model and Monte Carlo simulation.**

Setting: **The US healthcare system over a maximum 10-year lifetime horizon.**

Participants: **A hypothetical cohort of 60-year-old male patients undergoing elective OPCAB surgery or standard CABG surgery.**

Interventions: **Each patient was entered into the decision tree with varying transition probabilities. Outcome measures included quality-adjusted life-years (QALYs) and costs in US dollars.**

Measurements and Main Results: **In base-case analysis, OPCAB surgery led to a discounted lifetime cost of $91,282 and 7.64 discounted QALYs, and standard CABG surgery led to $91,685 and 7.52 QALYs. Patients who required conversion from off-pump to on-pump surgery incurred a cost of $103,909 and gained 6.63 QALYs. OPCAB is dominant (less costly and more effective) if the conversion rate is below 8.5%, whereas costs increase exponentially if the probability of conversion exceeds 15%. Sixty-one percent of the Monte Carlo simulations favored cost-effectiveness of the OPCAB strategy.**

Conclusion: **In low-risk patients, OPCAB surgery, in comparison to standard CABG surgery, would increase QALYs by reducing complications related to cardiopulmonary bypass, but it would result in lifetime costs similar to those of standard CABG surgery. The benefit of OPCAB may be offset by the risk of intraoperative conversion.**

KEY WORDS: off-pump, on-pump, statistics, risk analysis/modeling, health economics, computer simulation

OFF-PUMP CORONARY ARTERY BYPASS (OPCAB) surgery has become a widely accepted procedure for surgical myocardial revascularization. Several randomized trials[1-4] and meta-analyses[5-7] have indicated that the short-term outcome after OPCAB surgery is comparable to that after coronary artery bypass graft (CABG) surgery with cardiopulmonary bypass (standard CABG). However, long-term morbidity, mortality, quality of life, and costs associated with the 2 surgical strategies for myocardial revascularization have not been investigated to date.

OPCAB surgery eliminates many of the complications associated with cardiopulmonary bypass; however, some patients require intraoperative conversion from off-pump to on-pump CABG surgery because of hemodynamic instability, myocardial ischemia, or inability to visualize the target vessel.[8-11] Patients converted from OPCAB surgery to standard CABG surgery are reported to have a poorer prognosis and may therefore have a poorer quality of life.[9,10] Unlike standard CABG surgery, the OPCAB procedure does not always provide a motionless and bloodless surgical field, and it imposes time constraints on surgeons attempting to anastomose the graft. Graft quality may thus be sacrificed,[2,12] which would compromise completeness and longevity of revascularization over the long term.

The authors hypothesized that costs and quality of life associated with OPCAB may be influenced by these complicated issues including intraoperative conversion to on-pump CABG surgery. To determine whether conversion to standard CABG surgery reduces quality of life or increases costs, the authors performed a cost-effectiveness analysis in a simulated patient population by using a decision-analysis model with a Markov state-transition model and Monte Carlo simulation.

METHODS

The authors simulated a hypothetical cohort of 60-year-old male patients undergoing single- or multiple-vessel bypass under elective OPCAB surgery or standard CABG surgery. On the basis of weighted means derived from recent randomized controlled trials,[1-4] the hypothetical cohort consisted of the following: 49% of patients in Canadian Cardiovascular Society class 0, I, or II; 54% of patients with hypertension; 20% of patients with diabetes mellitus; and 68% of patients with normal left ventricular function (ejection fraction >50%). This was considered a cohort of "low-risk patients." The cohort represented users of the US healthcare system over a maximum 10-year lifetime horizon. Standard surgical techniques were assumed in the model. A hybrid decision tree was constructed that terminated in a Markov state-transition model by using TreeAge Pro 2007 Suite (TreeAge Software, Inc, Williamstown, MA). The model consisted of 2 major parts: a perioperative part (decision tree) and a postoperative part (Markov model).

In the perioperative part (Fig 1), a patient is entered into 1 of the 2 decision branches (OPCAB surgery or standard CABG surgery). In each branch, the patient is entered into either the scheduled procedure or the conversion procedure (from OPCAB to standard CABG surgery or vice versa). Each patient is then entered into the decision tree with varying transition probabilities. Other factors considered in this model

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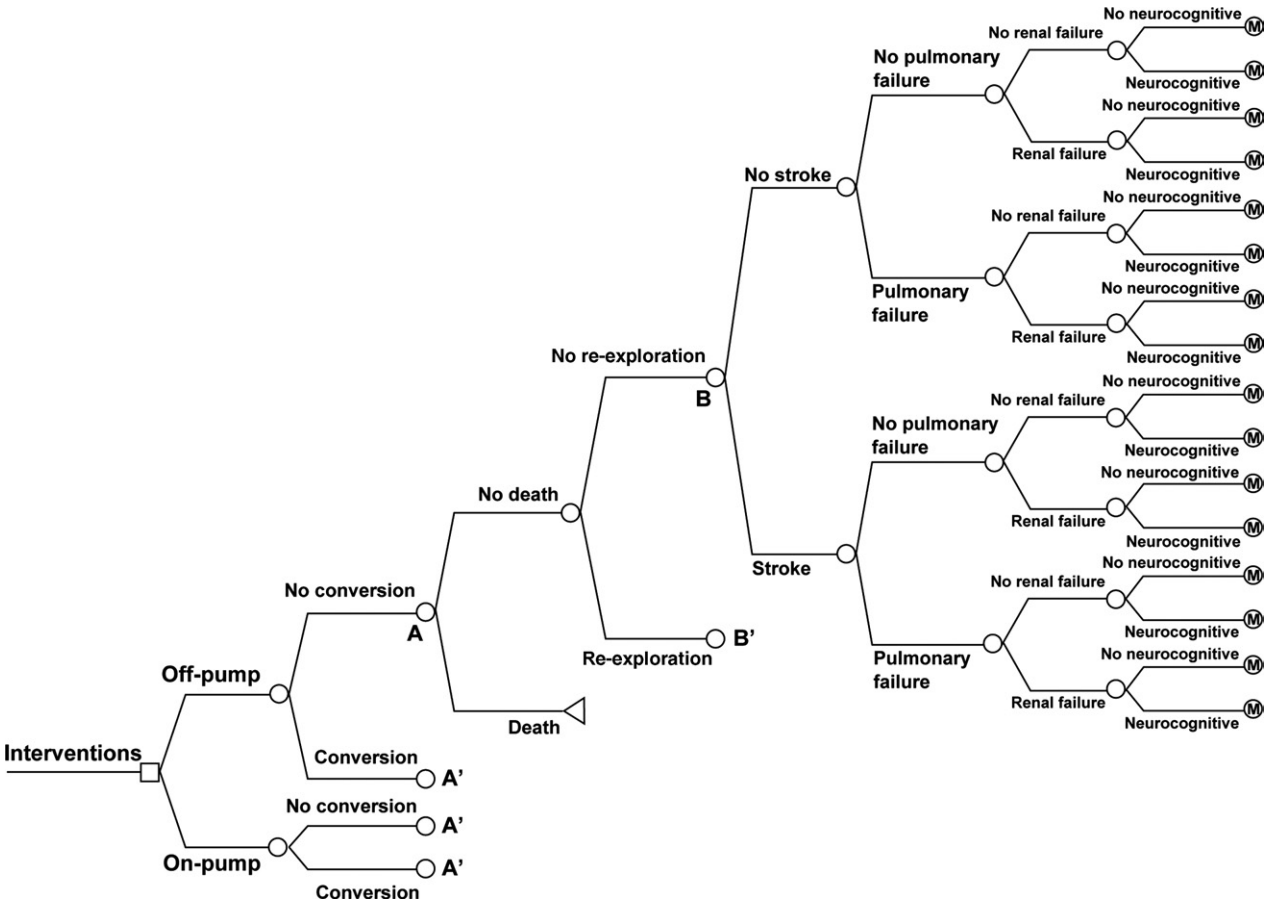

Fig 1. A simplified diagram of the decision tree (perioperative part). The square represents a decision node; in this case, the patient enters either the OPCAB surgery or standard CABG intervention branch according to the surgeon's choice. Circles represent chance nodes; a patient may have multiple possible complications according to assigned probabilities for each intervention. Circles with "M" are connected to the Markov model in part B (Fig 2). The triangle is the terminal node of the tree, in this case, death. The tree actually consists of a total of 63 variables and 2,823 nodes but was folded at A′ and B′ because of space constraints. A′ and B′ represent copies of trees A and B, respectively. Model structure is the same after both interventions, but transition state probabilities and costs associated with each intervention differ. Re-exploration = re-exploration for bleeding; neurocognitive = neurocognitive dysfunction.

are in-hospital mortality and morbidity including re-exploration for bleeding, stroke, pulmonary failure, renal failure, and neurocognitive dysfunction.

In the postoperative part (Fig 2), a patient is entered into a Markov state-transition model that consists of 8 health states: asymptomatic, recurrent angina, myocardial infarction, repeated CABG surgery or percutaneous transluminal coronary angioplasty (PTCA), postrepeated CABG surgery, post-PTCA, and death.

Probabilities of perioperative mortality and morbidity in patients who underwent OPCAB surgery, in those who underwent standard CABG surgery, and in those who were converted from OPCAB to standard CABG surgery were based mainly on the Merged Cardiac Registry,[9] a database containing records of 70,514 surgical coronary revascularizations. Probabilities of postoperative mortality and morbidity were obtained from published randomized trials and observational studies (Table 1).

The authors estimated the health-related quality of life of patients who underwent cardiac surgery on the basis of previous reports (Table 1). Utility of the postoperative state in patients who underwent OPCAB surgery and those who underwent standard CABG surgery was deemed identical unless complications associated with surgery occurred. In brief, a utility of 1 was assigned to complete health, and a utility of 0 was assigned to death from any cause. The utility values were based on standard gamble or time-tradeoff techniques.[13] If no data existed, the authors used estimated values and examined a wide range of values in sensitivity analyses. The utility associated with myocardial infarction or angina was estimated from data obtained from the Bypass Angiography Revascularization Investigation.[14] The utility associated with stroke was estimated from a recent cost-effectiveness analysis of minimally invasive internal thoracic artery bypass versus percutaneous transluminal coronary angioplasty.[15]

Costs used in the model for patients in each of the clinical states were derived from previously published estimates for surgical procedures, treatment, hospital care, outpatient care, medications, office visits, and laboratory tests. Physician costs were estimated on the basis of Current Procedural Terminology codes for 2006.[33] Drug costs were based on the 2006 Red Book average wholesale prices.[34] An incremental cost-effectiveness ratio between $0 and $50,000 per QALY is generally considered "cost-effective" (more costly and more effective) and that below $0 per QALY is considered "dominant" (less costly and more effective).[35] The authors discounted all life-years and costs at a rate of 3% per year following the recommendations of the US Panel on