

Chapter

ECONOMIC OUTCOMES OF OFF-PUMP CORONARY ARTERY BYPASS GRAFTING

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ABSTRACT

With the percentage of gross national product allocated to healthcare continuing to rise in the Western world, resource allocation has become an issue. Percutaneous coronary intervention continues to be a viable option for many patients, with lower initial costs. However, long-term angina-free results often require further interventions or eventual surgery. Once coronary artery revascularization therapy is selected, it is worthwhile to evaluate the cost considerations inherent to various techniques. Off-pump coronary artery bypass graft surgery has seen a resurgence, with improved technology and lower hospital costs than on-pump bypass surgery. Numerous factors contributing to cost in coronary surgery have been studied and several are documented here, including the potential benefits of early extubation and the use of standardized optimal care pathways. A wide range of hospital-level cost variation has been noted, and standardization issues remain. With the advent of advanced computer-assisted robotic techniques, a push toward totally endoscopic bypass surgery has begun, with the eventual hope of reducing hospital stays to a minimum

while maximizing outcomes, thus reducing intensive care unit and stepdown care times, which contribute a great deal toward overall cost. At the present time, these techniques add a significant premium to hospital charges, outweighing any potential length-of-stay benefits from a cost standpoint. This chapter aims to discuss the economic value of coronary revascularization, with a focus on coronary artery bypass grafting and its alternatives.

INTRODUCTION

Coronary revascularization, among the most common major surgical procedures performed worldwide, is both high cost and high revenue for hospitals. In 2010, total health care costs for major cardiovascular disease were \$503.2 billion [1]. Attempts to reign in the high cost of health care have proven to be difficult. Perhaps one of the most significant shortcomings in this task is that hospitals tend to have poor cost calculating measures [2]. Without a thorough understanding of the resources required to perform coronary revascularization, the medical community cannot determine where and how to best control cost. Understanding how resources are utilized to offer desired patient outcomes is an important step in creating an understanding of the costs and benefits of various therapeutic options.

The objective of this chapter is to discuss the economic value of coronary revascularization, with a focus on coronary artery bypass grafting (CABG) and its alternatives.

UNDERSTANDING COST

A “value framework” is required for understanding costs associated with CABG. This refers to understanding patient outcomes in comparison to the costs of this procedure. Most often, variable costs are included in such an analysis and include the price of the materials and supplies used during hospitalization (operating room[OR] supplies, blood products), cost of hospital stay (intensive care unit time [ICU], ward time), and outpatient appointments, in addition to any costs to manage complications or revise unwanted outcomes. However, there are additional cost considerations for this procedure that are not often considered including lost productivity during convalescence, such as leave from work, lost salary or utilization of sick pay. There are also less tangible, though significant, issues such ongoing underemployment for patients that return to work after a lengthy recuperation (Figure 1).

DIFFERENCES IN COST BETWEEN PERCUTANEOUS INTERVENTION AND CABG

There are two main options that provide coronary artery revascularization: CABG and percutaneous coronary artery intervention (PCI) using angioplasty and stenting. In a cost analysis of the largest prospective randomized comparison of CABG vs. PCI performed to date (i.e. SYNTAX trial), the index cost for PCI was found to be just over \$31,000 while the index cost of CABG was more than twice that, at just over \$63,000 [3]. The main drivers of increased cost for CABG are the additional resources required for the operating room, including increased

staffing costs, and increased length of stay in the hospital [4]. Although cost of materials for the index procedure is higher with PCI by over \$6,000, the total cost of index hospitalization is higher with CABG once taking into consideration physician fees and length of stay [4].

At one year following index hospitalization, PCI patients have a higher incidence of requiring revascularization procedures [4]. Follow-up for PCI was associated with increased costs for repeat hospitalization, medication costs, and physician costs (though CABG was associated with higher rehabilitation costs) [4]. While the follow-up costs for PCI patients are higher at one year by over \$2000 (e.g. costs of repeat revascularization, additional medications and clinic visits, etc.), this does not offset the high cost of the index hospitalization for CABG. As a result, the total one-year cost of CABG is just over \$3,000 higher than PCI [4]. However, the cost differences between these two modalities vary depending on the complexity of the coronary anatomy. In comparison to those with coronary artery lesions of mild to moderate complexity, patients judged to have the most severe complexity (i.e. SYNTAX scores above 32) showed a significant improvement in cost per quality-adjusted-life-years (QALY) gained at 1 year when treated with CABG [4].

From the perspective of the costs to society for treating coronary artery disease, PCI has been considered as a classic example of a “disruptive innovation” that results in similar clinical outcomes for selected candidates with dramatic improvement in costs during and after hospitalization. In addition to greater reimbursement costs of CABG, it has been demonstrated that the longer recovery period associated with CABG results in disability costs that were \$8,114 higher than PCI. For patients actively employed at the time of their procedure, absenteeism costs were \$5,500 higher for CABG vs. PCI [3].

<u>Provider Costs</u>	PCI	CCABG	OPCAB	RCAB
Materials for Initial Procedure	Guide wires, Stents, Contrast	Surgical supplies, cardiopulmonary bypass supplies	Surgical supplies, cardiac stabilization device	Robotic supplies, surgical cardiac stabilization device
Staffing cost for procedure	Assistants, technicians	Nursing	Nursing	Nursing
ICU cost	Lower LOS than CABG	Higher LOS than PCI	Lower LOS than CCABG	Lower LOS than Sterotomy CABG
Ward cost	Lower LOS than CABG	Higher LOS than PCI	Lower LOS than CCABG	Lower LOS than Sterotomy CABG
Cost of re-intervention	Higher than CABG	Lower than PCI	Same as CCABG	Same as Sterotomy CABG
<u>Social Costs</u>				
Hospital fees	Lower than CABG	Higher than PCI	Same as CCABG	Same as Sterotomy CABG
Professional fees	Lower than CABG	Higher than PCI	Same as CCABG	Same as Sterotomy CABG
Time lost to hospitalization	Lowest	Highest	High	Low
Cost of rehabilitation	Lowest	Highest	High	Low
Productivity lost to recovery	Lowest	High	High	Lower
Long term consequences	Restenosis	Neurocognitive changes (rare)	Neurocognitive changes (rare)	Fewer than Sterotomy CABG

Figure 1. Sources of cost. Although prices and reimbursements will change based on individual contracts or government policy changes, a conceptual understanding of cost will help providers calculate individual cost to benefit ratios of each option.

This lost worker productivity has further downstream effects on employers and therefore society including the need to hire and train replacement workers, the risk of underemployment when the patient returns to work and the financial impact on family caregivers.

DIFFERENCES IN COST BETWEEN OFF-PUMP CORONARY ARTERY BYPASS GRAFTING AND ON-PUMP CABG

The largest prospective comparison on on-pump vs. off-pump CABG (i.e. ROOBY trial) demonstrated that on-pump CABG had a higher resource requirement than off-pump coronary artery bypass (OPCAB) grafting. Patients undergoing on-pump CABG spent longer time in the OR (approx. 42 minutes) and required more blood products. Length of stay in the ICU was higher as well, though ward time was comparable [5]. Overall, this resulted in an additional \$2,284 in costs over OPCAB [5]. Numerous other trials corroborate comparable improvements in cost effectiveness for OPCAB [5,6]. Each of these studies show that cost is saved through efficient resource utilization by avoiding the disposable parts required to use cardiopulmonary bypass and the need for additional blood products. Many of the studies also show improved turnover time in the OR and ICU with fewer ICU re-admissions. In almost every study performed to date, health outcomes at one year have been equivalent between these techniques for the return of symptoms, survival, and quality of life. As a result, OPCAB has consistently demonstrated an improved cost per QALY over conventional CABG.

DIFFERENCES IN COST BETWEEN ROBOT-ASSISTED AND STERNOTOMY CABG

CABG can also be performed with less invasive surgical incisions using robotic assistance (RCAB). This appears to be a promising alternative to sternotomy CABG, although the widespread adoption of this technique has been limited. In an analysis performed by our group, the up-front costs of RCAB were found to be higher due to increased OR time, and the higher price of operative supplies and robotic instruments. However, the postoperative costs were considerably lower than CABG via sternotomy [7]. Cost savings were the result of a number of differences, most notably decreased length of stay, reduced requirement for blood products, and reduced lengths of stay in the ICU and hospital. These savings partially offset the intraoperative costs, resulting in only \$1,000 more total costs per case for RCAB than sternotomy CABG (Figure 2).

A conceptual tool for comparing outcomes between various healthcare options, called a Outcome Measures Hierarchy, can be used to define other potential economic advantages of RCAB over the alternatives [8]. The most important question regarding these three options is whether RCAB offers similar short and long term mortality. The few available studies suggest identical graft patency between the two options [9,10], despite a learning curve associated with initiating an RCAB program that has been documented to be as many as 100 cases [11]. One year results demonstrate improved patient satisfaction and a lower risk of major adverse cardiac and cerebrovascular events for RCAB vs. conventional CABG [12].

Most, but not all studies [13], have shown that RCAB has no difference in 3 year survival. Some surgeons believe that because the robot assisted technique requires less anatomic and physiologic manipulation. As a result, long term outcomes may be improved due to less neurocognitive and inflammatory changes in the perioperative period [14].

RCAB demonstrates its strengths over sternotomy based CABG among the dimensions of quality of life in the early postoperative period and time to return to normal functional status. Both of these parameters have been found to be considerably shorter amongst RCAB patients[12].

RCAB	Sternotomy CABG
Survival	
Same as Sternotomy CABG	Same as RCAB
Degree of recovery	
Identical graft patency to Sternotomy CABG	Identical graft patency to RCAB
Time to recovery	
Shorter time to recovery (2 to 3 weeks)	Typically, one-two months to return of normal activities
Disutility of care	
Improved cosmesis No risk of mediastinitis (except those requiring conversion to sternotomy) Reduced physiological and anatomical manipulation	Midline sternal scarring 1-2% risk for mediastinitis
Sustainability of recovery	
No difference in three year survival	No three year survival advantage
Long term consequences of care	
Potential for improved patient compliance with healthcare if decision for RCAB was part of a shared decision making strategy.	Unclear long term consequences on such issues as neurocognitive changes, higher inflammation during surgery, postoperative depression, etc.

Figure 2. A comparative outcomes measures framework comparing RCAB to Sternotomy CABG.

Of note, patients who required conversion to sternotomy CABG did not show any difference in outcomes to patients originally randomized to the sternotomy group. One study quantifying RCAB outcomes noted no morbidity and a markedly decreased length of stay [9]. Given that RCAB outperforms conventional CABG in time to recovery and disutility of care, it represents a very attractive option for patients and may be cost effective in terms of QALY gained. However, further analysis is required.

ADDITIONAL FINANCIAL BENEFITS OF RCAB

RCAB has the potential to offer additional benefits to health care providers, which may be more difficult to measure directly [15]. The designation of sternal infections as a “never event” by Medicare offers a strong incentive for procedures such as RCAB, which spare the sternum. Many patients eligible for CABG often have risk factors for sternal infection and mediastinitis, including patients who are obese, active smokers, or who have diabetes. Avoiding sternal incisions on these patients avoids the risk of being hit with the unreimbursed cost of managing mediastinitis, estimated at roughly \$50,000 per case. If avoiding sternotomy for half of CABG procedures can prevent two cases of mediastinitis per year, this would help hospitals forgo a cost of roughly \$100,000 per year.

Furthermore, stroke and mediastinitis are the two most costly complications for patients undergoing CABG. By avoiding aortic manipulation, RCAB offers an additional advantage reducing the risk of stroke. Both of these complications factor into the STS composite quality rating, which is publically reported and used by Medicare to drive pay for performance incentives. Currently, plans offer a 2% bonus payment for centers that are rated at “three stars”. For an institution that receives \$5 million in Medicare reimbursement, this would yield an additional bonus of \$100,000.

Shorter recovery time allows providers to leverage operational efficiencies as well. Efficient bed utilization helps offset the higher intraoperative cost. The ability to discharge RCAB patients 2-3 days earlier than CCAB allows hospitals to capture a larger share of DRG reimbursements as revenue, while also being able to use the available beds to treat other patients.

CONCLUSION

CABG is more resource intensive than PCI, but offers greater benefits in certain patient subsections. For patients that benefit from surgical revascularization, OPCAB uses resources more efficiently than conventional CABG. RCAB offers a promising alternative. While the intraoperative costs are higher, postoperative costs are lower, and benefits to patients may be greater. Understanding cost and resource utilization is important, especially given the recent stress on efficient use of resources.

REFERENCES

- [1] Mintel. (2010, December). *Heart Disease Statistics and Trends*. Retrieved from <http://academic.mintel.com/>.
- [2] Kaplan and Porter. How to solve the cost crisis in health care. *Harvard Business Review* 2011;89: 46-64
- [3] Zhao, Z., Winget, M. Economic burden of illness of acute coronary syndromes: medical and productivity costs. *BMC Health Serv. Res.* 2011;11:35.
- [4] Cohen, D. J., et al. Economic outcomes of percutaneous coronary intervention with drug-eluting stents versus bypass surgery for patients with left main or 3-vessel coronary artery disease: One-year results from the SYNTAX trial. *Catheter. Cardiovasc. Interv.* 2011 May 3. doi: 10.1002/ccd.23147. [Epub ahead of print]
- [5] Al-Ruzzeh, S., et al. Economic evaluation of coronary artery bypass grafting surgery with and without cardiopulmonary bypass: cost-effectiveness and quality-adjusted life years in a randomized controlled trial. *Artif. Organs* 2008;32:891-897.
- [6] Nathoe, H. M., et al. A comparison of on-pump and off-pump coronary bypass surgery in low-risk patients. *N Engl. J. Med.* 2003;348:394-402.
- [7] Poston, R. S., et al. Comparison of economic and patient outcomes with minimally invasive versus traditional off-pump coronary artery bypass grafting techniques. *Ann. Surg.* 2008;126:281-289.
- [8] Porter, M. E. What is value in health care?. *N Engl. J. Med.* 2010; 363:2477-81.
- [9] Atluri, P., et al. Off-pump, minimally invasive and robotic coronary revascularization yield improved outcomes over traditional on-pump CABG. *Int. J. Med. Robot* 2009;5:1-12.
- [10] Argenziano, M., et al. Results of the prospective multicenter trial of robotically assisted totally endoscopic coronary artery bypass grafting. *Ann. Thorac. Surg.* 2006;81:666-74.
- [11] Oehlinger, A., et al. Robotic endoscopic left internal mammary artery harvesting: what have we learned after 100 cases?. *Ann. Thorac. Surg.* 2007;83:1030-4.
- [12] Bonaros, N., Schachner, T., Wiedemann, D., et al. Quality of life improvement after robotically assisted coronary artery bypass grafting. *Cardiology* 2009;114:59-66
- [13] Jegaden, O., et al. Is there an optimal minimally invasive technique for left anterior descending coronary artery bypass?. *J. Cardiothorac. Surg.* 2011;6:37.
- [14] Gottesman, R. F., et al. Early postoperative cognitive dysfunction and blood pressure during coronary artery bypass graft operation. *Arch. Neurol.* 2007;64:1111-4.
- [15] Kurian, D., et al. Change management during the implementation of an innovative approach to heart bypass surgery. *Physician Exec.* (2011) In press.