Chapter 6

Opportunity Cost Analysis of Robotic Surgery

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ABSTACT

Several studies have established that a robotic surgical case, when compared to a conventional open procedure, adds approximately $3000/case to the hospital costs. The financial rationale for a robotic program depends on whether this extra cost "adds value" and yields a reasonable return on investment. Most often, the decision is justified by analysing whether robotics improves patient recovery and avoids the costs of convalescence associated with open surgery. An opportunity cost analysis is an alternative method that is often used to elucidate the question of value. Using this financial framework, we directly compare the economic value of cardiac surgical robotics with the next best alternative, namely open chest surgery. For a hospital choosing not to adopt robotics, we identify domains where costs are avoided and domains in which a hospital might forgo value. Ultimately, our analysis of opportunity costs favours a robotics program. A hospital providing only open cardiac surgery and no robotics program forgoes more than $1 million in the first year, despite substantial start-up costs. After the first year, these costs are quickly offset by improvements in postoperative costs and other factors that increase reimbursements relative to open surgery. We speculate that hospitals to ignore the favourable opportunity costs of robotic surgery based on cognitive and emotional biases that tend to sway decisions toward conservative options. Increasing awareness of these biases will likely lead to better financial decisions about robotics.

KEYWORDS: OPPORTUNITY COSTS, ROBOTIC SURGERY, CARDIAC SURGERY, HOSPITAL COSTS

6.1 Introduction

A surgical robot adds costs to surgery that are not seen with conventional laparoscopic or open procedures. The additional costs of a surgical robot are said to “add value” if they create benefits for patients (e.g. improved quality adjusted life years, quicker return to work productivity, etc.) that are not seen with the alternatives. The decision whether to initiate, support and sustain a surgical robotics program requires resources that are always scarce relative to needs. Maximizing the return on these resources is critical to the financial success of any hospital. Rational decisions about scarce resources recognize that commitment of money to one purpose prevents its use in other ways. In a similar manner, a more accurate financial picture of robotics emerges when comparing the results expected with the next best alternative (i.e. open or laparoscopic surgery), a form of financial reasoning known as an opportunity cost analysis.(1)

Previous studies evaluating costs of robotic surgery have found surprisingly similar results across many surgical specialties: a robotic approach adds ˜$3000 surgical cost per case.(2,3) This has proven true whether costs are measured based on billing records or in depth review of the medical records. Only one company, Intuitive Surgical, supplies the robotic technology and all its revenue comes from system, service, and instrument sales. This company’s financial statements disclose its total revenue and the total number of annual cases performed robotically across all specialties.(4) Comparing these two numbers shows that hospitals pay an additional ˜$3000 for every robotics case that is performed, confirming that this estimate of robotic costs is highly reproducible.

There is much less agreement about whether this $3000 cost adds value. Many say the robot yields no proven benefit while some suggest it avoids costs associated with the longer recovery period after open surgery and mitigates other drivers of variable costs by reducing postoperative complications and length of hospital stay. However, few studies have employed an opportunity cost framework to address this question of value in a more comprehensive manner. The purpose of this chapter is to use an opportunity costs analysis to show the value added to the hospital by robotics, specifically a cardiac robotic program. Cardiac robotic surgery differs from open surgery in that access to the heart is gained through small incisions between the ribs (minithoracotomy) rather than the sternum (sternotomy).

Given the strength of the evidence from our opportunity cost analysis, it is natural to ask why more cardiac surgical programs have not adopted robotics. Accordingly, we will describe systemic factors and biases that have likely hindered the strong impact that an opportunity cost analysis would be expected to have on cardiac surgery and the wide range of other surgical specialties contemplating a surgical robotics program.

Several studies from almost every surgical specialty have documented that less invasive surgical methods reduce costs.(5) The field of cardiac surgery has been one of the slowest to adopt these techniques. Conventional, open chest cardiac surgery is critically important to the viability of a hospital, in part because of its solid track record of financial contributions.(6) Yet there is clearly an opportunity for improvement. The risk of a prolonged length of stay due to a complication is higher than almost any other elective procedure and the volume of cases performed at most centers has been steadily declining for the last two decades. These issues increase the variable and fixed costs of cardiac surgery, respectively.(7,8)

Robotic cardiac surgery was first introduced two decades ago. Since that time, several expert cardiac surgical centers have proven this procedure to be as safe and effective as open cardiac surgery and associated with quicker recovery and less complications.(9,10) Thus for hospitals that perform only open cardiac surgery, a viable alternative creates an opportunity cost that is defined by the forgone advantages and disadvantages of the robotics:

6.2 Value Forgone by a Program Choosing Not to do Robotics

6.2.1 Robotics Reduces the Risk of Postoperative Complications

The typical cardiac surgery program has about 200 coronary artery bypass grafting

(CABG) cases/yr. With this volume of cases, a program is likely to have 30 patients per year suffer major postoperative complications. It has been estimated that each of these events increases costs by approximately $50K/case. Stroke and mediastinitis are the two most costly complications after CABG. By avoiding aortic manipulation and the sternotomy, the robotic approach is inherently well-suited to reduce the risks of these events. Evidence demonstrates that the cost reduction is the greatest in those patients that are the highest risk for postoperative complications.(11,12)

Cost calculation: It is reasonable to predict that diverting 100 out of 200 cases/year to a robotics approach would prevent 10 complications/year. Each complication adds $50K in expenses that go unreimbursed given fixed DRG payments. Therefore, this impact from a robotics program yields a savings of $500K/yr.

6.2.2 Robotics Reduces Never Events (i.e. Mediastinitis) Compared to Sternotomy

One of the most obvious advantages of robotic surgery is the ability to avoid sternal infection and its costs that are conservatively estimated at $50K/case. This complication has recently been designated as a "never event" by Medicare, which means that the costs of mediastinitis are unreimbursed. This creates an important financial risk to open CABG programs, particularly for those with a high proportion of patients with obesity, active smoking, and diabetes, risk factors that increase the risk for sternal infection. By avoiding a sternal incision, robotic CABG mitigates mediastinitis, even for the highest risk cases.

Cost calculation: Avoiding the sternotomy for a portion of cardiac surgery cases (100 robotic cases/year) is expected to prevent two annual cases of mediastinitis per year, particularly since case selection for robotics is based in part on the risk of a sternal infection. At $50K/case, this advantage would provide the hospital with $100,000/yr.

6.2.3 Robotics Improves the Quality Rating Leading to a Medicare Bonus Payment

Less risk of complications with robotic surgery improves a publicly reported score called the "STS composite quality rating." This is used by many patients and referring providers to select surgical programs. Medicare uses these same measures to derive its pay-for-performance plan, called the Merit-Based Incentive Payment System.(13) Centers rated as achieving exceptional performance (i.e. "three stars" by STS) are eligible for up to a 13.5% bonus payment.(14)

Cost calculation: This bonus is based on Medicare part B reimbursements, which for a cardiac program of 200 cases/yr is approximately $700K/yr. If robotics enabled a 3 star rating, it would yield a bonus to the hospital for exceptional performance of $94,500.

6.2.4 Robotics Uses Bottleneck Resources More Efficiently

There is often insufficient OR and ICU space to meet demand, which restricts the throughput of patients into and through a hospital. Cardiac surgery patients require more OR and ICU resources than other surgical patients. Therefore, the routine discharge of robotic cardiac surgery patients two or three days sooner than expected is a particularly valuable advantage. When this happens at hospitals at or near full occupancy, it allows a new patient to be admitted into that open bed who would have otherwise been turned away. Beds saved by robotics are most likely to be filled by patients within the same specialty, which enables new revenue to be captured by the CT service line.(15)

Cost calculation: Earlier discharge after a robotic case provides 2 extra bed-days compared to open cardiac surgery. Given a volume of 100 robotic cases/year, this yields 200 bed-days. For a hospital at full capacity, each of these extra days provides $10,000/day of incremental reimbursement or $200,000 additional revenue to the hospital per year.

6.2.5 Increased Case Volume

An explosive growth of health information has led to a consumer base as well-informed as it has ever been. This creates a unique opportunity to market distinctive programs such as robotic surgery directly to consumers. Prior evidence has shown that patients often have unmet information needs about less invasive surgical options (16,17) and view a hospital's marketing efforts in this area as a helpful and legitimate source for information.(18, 19)

Cost calculation: Our previous experience with marketing efforts focused on robotic surgery generated 50 additional cases per year via word of mouth or self-referral. Assuming typical profit margins of $5,000 per case, an additional 50 cases that come to the hospital solely for robotic cardiac surgery would yield $250,000.

6.2.6 Improved Hospital Reimbursement

Hospital revenues directly relate to how much reimbursement they receive from insurance companies, which is determined the proportion of admitted patients who have private insurance ("payer mix") and by the complexity of cases that the hospital treats ("case mix index", CMI). Some payers reimburse cardiac surgery enough to yield profits of nearly $20K/case (e.g. Blue Cross-Blue Shield). Medicare and Medicaid provide very little profit per case, but increase their payments for all beneficiaries in response to factors that increase the hospital's CMI. Cardiac surgery cases have a DRG relative weight is 6-8 times higher than the typical hospital inpatient. Anything that increases the number of highly weighted cases will drive up both the CMI and Medicare reimbursement to the hospital.

The idea of surgical robotics is highly marketable, which means that a new robotics program has the potential to recruit a significant number of patients into the hospital from outside the typical catchment area. This generally results in a patient population with a more favorable payer mix.(20, 21) One year after the introduction of robotic cardiac surgery at Boston Medical Center, it was noted that the ratio of "government" (Medicare/Medicaid) to private payers changed from 2:1 to 1:2.(22) Quicker return to work of the patient is highly valued by employers, which gives the hospital leverage to negotiate contracts and increase reimbursement for their surgical services.

Cost calculation: As a result of a more favorable payer mix and the ability to negotiate better contracts, robotic cases at our center were reimbursed $2,000 more than sternotomy CABG. For a program performing 100 robotic cases/yr, this differential is expected to yield a net benefit of $200,000/yr. An additional volume of 100 robotic cardiac cases/year was noted to increase the hospital's CMI from 1.31 to 1.55. This increased Medicare reimbursement at our center by $200 for every patient (our hospital has 10,000 admissions per year), which led to a total added revenue of $1 million/yr.

6.2.7 Higher Levels of Patient Satisfaction

Less invasive surgery is a distinctive therapy and has an established track record at improving patient satisfaction in a variety of surgical fields, including cardiac surgery. Satisfaction scores are now publicly reported and this information is being sought after by prospective patients online. It is imperative for hospitals to have an effective plan for maximizing these scores. One option is to develop patient friendly surgical innovations like robotic surgery, which is less costly than other common proposals such as reducing patient-to-nurse ratios or changing semiprivate beds to private.(23)

Cost calculation: Initiating a robotic cardiac program may involve added costs but this is generally reimbursed by insurance at no cost to the hospital. The cost of the other two strategies are unreimbursed and typically cost the hospital $200–500K/yr. If a robotics program improves satisfaction alone, it can avoid the need to take on these other costs.

6.2.8 Better Performance in “Bundled Payment” for Care

The cost of hospitalization to perform surgery has been reimbursed as part of a global payment called a diagnosis related group (DRG). Other various aspects of surgical care such as professional fees and postacute care are covered a la carte. Medicare has initiated a new program for paying for certain types of surgery that limits these additional hidden costs. Going forward, Medicare (and likely followed by other insurers) will provide a bundled payment that covers all aspects of care for a 90-day period surrounding surgery.(24) This reimbursement model creates a financial risk to the hospital depending on whether the actual costs required for surgery are less than or more than the payment received. Robotic surgery has been shown to reduce the need for postacute care compared to open surgery from 30% to 15% of discharges (15 less cases sent to rehab per yr) and therefore can reduce this financial risk.(22)

Cost calculation: The costs of inpatient rehab are $10K/case and are avoided in 15 patients/yr with robotics. This results in a $150,000 savings. In a bundled payment model, this savings is split with CMS so $75K goes to the hospital.

6.3 Value of Avoiding Robotics

6.3.1 A Full Sternotomy Minimizes Perceptions of Poor Safety

Depending on the status of the patient, the operative plan for any less invasive surgical case can always suddenly change to an open procedure. This conversion from robotic to open creates a risk for preventable patient harm that would not happen if the case were done open from the start. Deciding when, if and how to employ a so-called "bailout maneuver" increases the complexity of robotic surgery. However, it does not make it inherently unsafe. A metaphor for its safety is the generation of electricity from nuclear power compared to conventional methods. Nuclear energy adds new hazards that are well known since Three Mile Island. However, the vigilance of teams that operate these plants have eliminated any impact on the US public from nuclear hazards in the 40 years since that accident.

Cost calculation: A robotic program must strive for the same high performance of nuclear power plants in order to be safe. This requires resources well beyond what is available to the status quo procedure. Staff must be dedicated to robotics with no substitutions and given the necessary time off for regular training and debriefing sessions. In order to focus on robotic cardiac surgery, OR staff will not be available with non-CT surgery cases and these staff are not easily replaceable. This shift in resources might reduce the overall number of OR cases by one case per day (200/yr) at a hospital with ORs at full capacity. The return on investment is greater for cardiothoracic surgery than most other surgical services ($5000 vs. $2000K/case), which would mitigate the revenue losses. However, this would increase costs during the first year of the program by around $200K.

6.3.2 There is No Learning Curve for Open Surgery

All robotic programs must endure an initial long and potentially hazardous initial phase of on-the-job learning where team performance gets worse before it gets better.(25) This phase—not associated with mature procedures like open surgery—is well-known to degrade performance as measured by longer OR times, more complications and other inefficiencies.

Cost calculation: Prior analyses of cases performed during the learning curve phase (typically 100 cases) showed $4000 added costs/case compared to cases performed after the learning curve phase.(26) The total added costs of the learning curve: $400K.

6.3.3 Open Surgery Avoids the Need for Start-Up Costs

Open surgery is well understood to patients and their referring providers, but robotic surgery is not as well known for many specialties. A study of robotic marketing demonstrated that the strong valance of robotics as an advertising message can lead to new patient referrals.(21) This potential for new volume, along with the hospital's desire to show a return on investment, creates a strong rationale to market robotic programs and this costs money. In addition, there are other one-time expenses for equipment, labor, supplies and training required to start the program.

Cost calculation: These one-time expenses are incurred at the outset of the program and vary depending on the hospital's available budget. As an example, Boston Medical Center spent $350K to advertise robotic CABG at the outset of their program.(21) The other start-up costs approach $300K.

6.4 Factors Irrelevant to the Opportunity Costs of Robotics

6.4.1 Costs of Poor Team Morale

Robotics adds complexity to already challenging procedures like cardiac surgery. When patients suffer complications after robotic surgery, it can lead staff to perceive that added complexity as unsafe and to become demoralized about the program. Problems with morale are often reflected in HR costs such as increasing staff turnover and absenteeism. However, this is often inappropriately attributed to robotics. Any task as complex as cardiac surgery – whether done open or robotically – is vulnerable to problems with safety and morale. Multiple prior studies have documented that roughly 50% of complications after open cardiac surgery are caused by preventable errors like poor communication and ineffective teamwork.(27, 28) Other industries that routinely navigate high risk and complex tasks such as aviation or nuclear power plants have dramatically reduced teamwork errors by creating a culture known as the high reliability organization. According to a recent publication from the Joint Commission, there are no hospitals in the US that have the fundamental aspects of a high reliability organization.(29) The link between morale and outcomes exists for either procedure. Because of this, HR costs associated with morale problems is not a relevant opportunity cost of robotics.

6.4.2 Capital Costs of the Robot

Many cost effectiveness studies consider the capital costs of the robot in their comparisons with open surgery. Amortized costs are highly dependent on usage of the robot, which varies greatly between institutions and whether robotic costs are spread across multiple surgical specialties. Purchasing a robot entails a "sunk cost," meaning a cost that cannot be recovered once it has been incurred. Such costs are highly relevant to a decision to purchase the robot based on understanding the total cost-benefit of ownership.(30) However, it is not economically rational to include amortized cost when analyzing the cost effectiveness of robotic procedures done after its purchase. This can be compared to the cost of building a hybrid operating room for transcatheter aortic valve replacement (TAVR). The cost of a hybrid OR has not been incorporated into any of the analyses comparing TAVR to traditional aortic valve replacement.(31, 32) It is inappropriate to hold robotics to a different standard than for other innovations. (Table 6.1)

6.5 Summary of Analysis

An opportunity cost analysis of robotic cardiac surgery demonstrates that a program performing 100 cases/yr would likely yield an incremental profit of over $1 million in the first year. The added profit would be expected to increase to $1.5 million/year thereafter because the expenses associated with a shift in staffing, learning curve and other startup costs are only incurred during the first year of the program.

While our analysis of robotic surgery is relevant to any surgical specialty, the magnitude financial benefit is likely to be less favorable in fields outside of cardiac surgery. The Canadian Agency for Drugs and Technologies in Health performed an economic analysis of robotic-assisted surgery across multiple specialties.(33) Their report estimated cardiac surgery to show the greatest financial benefit from robotics amongst all specialties, with a net program cost of less than $1 million over 7 years. The financial value in cardiac surgery was attributed primarily to a relatively greater impact on hospital stays and complications versus other specialties.

6.6 Robotic Costs: Perception vs. Reality

Our opportunity cost analysis adds to a growing evidence base in support of the value proposition of robotics, particularly for those specialties with the most morbidity and longest lengths of stay after open surgery (e.g. cardiac and thoracic surgery). However, the majority view remains skeptical about the value of robotics in CT surgery.(34, 35) Misperceptions about the long-term financial value of this program make it more difficult for hospitals to invest fully in the required start-up costs. Without these investments, robotic programs are more likely to struggle with the learning curve and ultimately fail.

The judgment if the long-term value of a proposed project justifies the up-front startup costs is an important fiduciary duty. The accuracy of any decision is influenced by two facts: 1) up-front costs are tangible, explicit, and easy to quantify and 2) evidence of long-term value is often intangible and implicit, particularly if value is defined mainly by opportunity costs. Psychological research shows that most decisions are based on information that is explicitly presented and available to decision-makers.(36) This set of circumstances creates a tendency for stakeholders to ignore opportunity costs, which biases decisions against innovations whose value is defined by implicit concepts like opportunity costs.

Other biases influence how the finances of a new robotics program is interpreted. The principle of loss aversion motivates people to place a higher priority on avoiding extra costs than to acquire equivalent gains. This creates undue concerns about the added costs of the learning curve. The certainty effect, time discounting and projection bias makes people overvalue outcomes that are certain and available immediately. The learning curve phase has an unpredictable impact on costs and varies widely between surgical programs, which creates uncertainty about financial risk. The need to go through a learning curve phase means that the value of robotics does not become fully evident until sometime in the future. Any benefit that must be deferred into the future—even though it might serve long term goals—is perceived as less valuable than one produced right away. All these cognitive errors lead surgeons and hospital administrators to perceive the learning curve as overly problematic even as the robotic program contributes to the financial bottom line.

Decisions about robotics can also be distorted by emotional factors. Traditional open cardiac surgery is a procedure that has created a strong sense of ownership among its many stakeholders. This promotes an "endowment effect," or an irrational tendency to overvalue open cardiac surgery and underestimate its opportunity costs. Trying to persuade many surgeons about the value of robotics is like trying to convince skeptics about global warming. The root cause of the problem is not a lack of understanding of the data but a conflict of interest.(37) Progress in medicine does not depend just on the search for truth, but also a social process in which proponents of robotic must convince others of how the evidence should be interpreted. Surgeons whose reputations and even sense of self are tied to the status quo have little incentive to accept these interpretations.

6.7 Conclusions

There are many legitimate reasons why a hospital and surgical team may prefer to use only the traditional open techniques for their patients referred for surgery at their program. However, our opportunity cost analysis illustrates that concerns about value should not be one of those reasons. While the costs of robotic surgery are increased at the outset of the program, these costs are quickly compensated for by improvements in postoperative costs and other factors that increase reimbursements relative to open surgery. The learning curve triggers cognitive and emotional biases that lead decision makers to overemphasize financial hazards and ignore opportunity costs. These biases can cause irrational financial decision making and serve as another source of financial risk.(38) Knowledge of these biases can reduce the judgmental errors in financial decision making.

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TABLE 6.1

OPPORTUNITY COSTS OF PROVIDING ONLY OPEN CARDIAC SURGERY AND NOT DEVELOPING A ROBOTIC PROGRAM.

FORGONE VALUE		COSTS AVOIDED	
More complications	500	Increased OR costs $3000/case	300
More “never events”	100	Costs required to have dedicated staff	200
Lower MIPS score	94.5	Inefficiencies of the learning curve	400
Less efficiency with bottleneck resources	200	Start-up costs	650
Less favorable payor mix	200		
Improved CMI	1000		
Less volume	250		
Lower patient satisfaction	200		
Reduced success with bundled payment plans	75		
SUBTOTAL	-2,619,500		+1,550,000
TOTAL	$1,069,500		