Cost Benefit Analysis of Stents v. Other Surgical Options

A Major Qualifying Project Report submitted to the faculty of the WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science in Management Engineering by

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Abstract

Heart health is important for the overall normal function of the body. Given the complexity of all heart diseases, especially when each person’s experience is different, there are various options to help a patient become healthier. This MQP examines the effectiveness of several cardiac solutions to determine the best solutions for patients. Our primary focus is on the evolution of stents and a comparison of the commonly used stents to other surgical options.
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**Introduction**

Our primary focus is on the issues surrounding the health of the heart. With each medical issue, there are certain paths that a patient can take. We want to make sure patients are more aware of the potential surgical options and the issues that are associated with each route. Surgical solutions can be very costly depending on the severity of the disease, insurance coverage, doctor preference, and which option will be the most beneficial to the patient. Some options may have similar results and patients may undergo procedures that are unnecessary and overly costly when compared to other solutions.

The specific heart diseases that may result in the placement of stents or other procedures such as angioplasty, minimally invasive surgery and open heart surgery include coronary heart disease, angina, and myocardial infarctions (heart attack), which are all interrelated. Coronary heart disease occurs when the heart, the body’s pump, is damaged with resultant insufficient oxygen to the rest of the body. If this disease is severe enough, it could result in a myocardial infarction, but if less severe there may be strong signs of angina. For each of these heart diseases medications, stenting, angioplasty, and some kind of heart surgery can be used for treatment. Each of the treatments has its own costs, benefits, procedure time, recovery time, and long term and short term results.

The final result of our paper resulted in a comprehensive look at the heart itself, and some of the causes of heart malfunction mentioned. In order to clearly discuss the different types of surgical solutions for these heart diseases, we learned the evolution of heart surgery and the newer medical procedures, such as stents, that are available for patient use. We not only discussed stents that surround the heart, but how stents could be used in other areas of
the body. From there, we evaluated the pros and cons of stent use and the role that stents play in the surgical arena. Also discussed are the different surgical solutions besides stents that can be used. The possible future role of stents, including biodegradable stents, was also examined. After evaluating the uses and roles of stents, it was possible to evaluate comparative costs of each procedure and how one choice can impact future medical and financial decisions of the patient.

From our comprehensive comparison analysis, we were able to evaluate what type of procedure might be best for the patient and present our finding in a clear format.

**Problem Statement**

The heart is an organ that is vital for survival. The body requires oxygen to function properly, and the heart provides the mechanism to supply oxygen throughout the body. When doctors first began attempting to surgically intervene when the heart malfunctioned, the recovery process that followed was long and expensive. As surgical practices have evolved, the monetary cost of heart surgery has declined, as have the risks that patients have faced while undergoing such a procedure. However, it is imperative that research into advancing practices is continued in the hope that costs and health risks continue to fall. Money, time and long term results all need to be considered as a whole in order to assess the measures that need to be taken in order to make the best decision for each individual patient.
Methods

The goal of our project is to effectively raise patient awareness about not only surgical procedures but the costs associated with each procedure. In order to collect the most appropriate data, the tasks performed included the following:

1. Literature Review
2. Interviews

The literature review included extensive research on patents of the various types of stents, reviewing of scholarly articles and research about the costs of stents and the other types of procedures for cardiac diseases. The topics listed above are further elaborated on in the Discussion portion of this paper.

The interview conducted was with a professor from Worcester Polytechnic Institute, Satya Shivkumar. The notes from the interview are found in Appendix B. This personal interview proved to be very effective in obtaining the essential information for our project and in analyzing the problem.
Results

The four main options for different heart issues and disease were found to be medication, stents, minimally invasive surgery, and open heart surgery. Stents are thoroughly discussed because of the flexibility of the procedure. It involves a form of angioplasty, the use of medication, and small scale surgery to implant the stent in the precise location. The use of stents encompasses a number of components of other options to help with the heart issue.

The other surgical options discussed have higher percentages of risk for various matters than stents. Open heart surgery and minimally invasive surgery involve different sizes of incision in a variety of locations which may pose a threat to the body in terms of recovery. Stents also involve some risk with clot formation around the stent or the need for a new stent. All the options must be discussed and considered in order to assess the correct options for a patient depending on the complexity of their heart issue.
Discussion

The Heart

The heart is the pump of the body. A normal functioning heart distributes oxygen to all the tissues, maintains levels of nutrients and wastes, regulates body temperature, distributes body heat, and protects against blood loss through clotting. There are two networks or circuits of vessels and capillaries that transport blood to and from the lungs (pulmonary circuit) and deliver blood to the body and back to the heart (systemic circuit). The four chambers of the heart assist the two circuits. The right atrium receives blood, low in oxygen and rich in carbon dioxide, from the superior and inferior vena cava. From the right atrium, blood is pumped into the right ventricle then to the lungs. These two chambers service the pulmonary circuit. The left atrium receives re-oxygenated blood via the pulmonary veins. The left atrium and left ventricle pump blood into the aorta which supplies oxygen to all tissues and organs and picks up the cellular waste of carbon dioxide. The left atrium and left ventricle are part of the systemic circuit. (Figure 1)
Blood flows through a series of veins, arteries and capillaries, from the heart via arteries to the capillaries and back to the heart via veins. Arteries include the aorta, ones that are embedded to the heart muscle wall providing oxygen to the cardiac cells, and muscular arteries that give a person their pulse. Capillaries facilitate the exchange of nutrients and waste which form a branching network on all body tissues.

**Mechanism of Action of Platelets**

Platelets usually have a disc shape but when activated, they change into a compact sphere with cilia-like extensions that aid in adhesion. The localization and adhesion of platelets allows for the body to be protected from blood loss. The platelets secrete adenosine diphosphate (ADP), calcium and different proteins which allow for the surface membrane of
platelets to become ‘sticky’ and form a clot. This localization forms a clot to allow for proper healing of an affected area.

Such clotting is not ideal when a person is dealing with different heart problems such as plaque buildup, recent heart attack, narrowing of capillaries, etc. When a patient currently has some sort of heart problem, one of the common options for a first step is for a patient to take some type aspirin or Plavix. Aspirin is usually administered in order to thin the blood, enabling the blood to flow more easily and reducing the risk of a future clot. Plavix removes the stickiness from the platelets in order to keep from forming clots. These drugs can be taken in conjunction to stent placement, allowing for a lower risk of a blood clot forming on a stent, leading to further heart attacks and possibly death.²

**Reasons for Intervention**

Before a heart attack, coronary heart disease or angina occurs, there are preceding heart issues that can aid in the severity of a disease. A few of those include stenosis, high blood pressure, plaque buildup, and high cholesterol. Stenosis is the narrowing of the arterial walls whereas high blood pressure is associated with the hardening of arterial walls. Both of these can make it harder for the heart to pump the blood effectively. Plaque buildup is usually caused by high cholesterol and years of cholesterol buildup on the artery walls will create a blockage in the artery.³

Stenosis, high blood pressure, high cholesterol, and especially plaque buildup restrict the blood flow to the heart or to the rest of the body. Dizziness, shortness of breath, chest pain, fatigue, headaches may be caused by the lack of blood flow throughout the body. If any of the
conditions listed were to worsen, coronary heart disease or angina could be developed. This would cause persistent chest pain and the potential for additional heart issues. If a plaque buildup were to rupture, blood flow would drastically be reduced initiating heart muscle death and probable myocardial infarction.

The goals for each of these issues or diseases differ depending on the severity therefore requiring a specific solution or form of intervention. It may vary from changing life style habits for health to taking aspirin or Plavix to stenting or some kind of surgical procedure. Each of these options has a set of long term and short term goals in order to prevent a future incident and help a patient live longer.

**Drug Design**

Aspirins and Plavix are anticoagulants. Coagulation occurs with platelets and proteins, which platelets secrete upon activation. The two anticoagulants mentioned inhibit the clotting ability of platelets by making platelets ‘less sticky’ and increasing the clotting time. The antiplatelet agent or the anticoagulation of platelets in aspirin and Plavix is used because it decreases the risk of clotting in affected areas. The risks can include thrombosis, myocardial infarction, coronary heart disease, plaque buildup, and a stroke.$^4$

Though the involvement of the drugs has proved to be beneficial to those that suffer from some kind of heart problem, it can still involve some risk. A longer clotting time can cause for patients to bruise more easily. This blood loss can be prolonged after operations or just a nick on the leg. Even with the costs, in most scenarios, the anticoagulation of the blood is beneficial to an older patient or one with a heart condition.
**Design of Stents**

Stents are designed in such a way that they are collapsible, yet retain their tensile strength when deployed. As such, many bare metal stents are constructed using an alloy called Nitanol, which is a nickel-titanium alloy. This alloy allows for superior flexibility as well as allowing for a smaller profile when compared to titanium counterparts. Currently, there are two main stent designs, open cell and closed cell. (Figures 2 and 3) These have little difference in most mechanical functions, yet there appears to be a difference in the healing factors caused by the dissimilarities in cell design. In one study, there were no statistically significant differences in health factors caused by cell design, yet there was a numerical difference in outcomes. What occurred can be seen in Figure 3. Numerically, closed cell stents are safer for the patient than open cell stents, however the numerical differences did not translate into any statistically significant outcomes.⁵

![Figure 2: Open versus Closed Cell Stents](image)

- **A**: Open cell stent
- **B**: Closed cell stent
- **C**: Comparison of cell designs

⁵ Figure 2: Open versus Closed Cell Stents
Reasons for a Stent

Restenosis is the recurrence of stenosis, the abnormal narrowing in a blood vessel or other tubular structure. Restenosis in this case refers to the narrowing of a vessel following treatment. To date, no surgery has proven one hundred percent effective in preventing restenosis, although advances in technology have allowed for restenosis rates to decrease. In balloon angioplasty, the restenosis rate usually falls around forty percent, while traditional stents drop that rate to around twenty five percent.
When a bare metal stent is placed in the body, tissue begins to envelop the stent and covers the struts of the stent. This process is called endothelization and is necessary for the healing of arterial walls. In the early stages of healing, the tissue growing is healthy cell wall tissue from the arterial wall of the blood vessel. Later, scar tissue could form underneath the new tissue. If this layer of tissue is too thick, it could obstruct normal blood flow, and cause similar health complications as the original problem. (Figure 4)

One of the other issues with stents is incomplete endothelization of the stent struts, which can lead to stent thrombosis. Incomplete endothelization is when the arterial wall cells do not completely cover the stent struts. (Figure 5) The body reacts to the foreign body inside the vessel, and both platelets and white blood cells converge on the struts. The platelets begin to form a clot, which could eventually detach from the vessel wall and cause either a
myocardial infarction or a stroke. Late stent thrombosis (LST), which occurs later than one month following surgery, is a large problem in patients who receive a drug-eluting stent. In bare metal stents, complete endothelialization is usually evident at around 28 days, whereas drug-eluting stents uniformly showed incomplete healing at 180 days, in one study. Late stent thrombosis has been documented in both clinical and autopsy studies in patients as far as four years after stent insertion. Late stent thrombosis was found to be most associated with a discontinuation of proper drug treatment or hypersensitivity to the polymer found in drug-eluting stents.

Figure 5: Restenosis of a stent
Evolution of Stents

Bare Metal Stents

In 1977, a process called Percutaneous Transluminal Coronary Angioplasty (PTCA) was developed. This process is a minimally invasive surgery that is intended to open blocked veins and arteries within the body by utilizing a balloon catheter. The catheter is inflated at the site of the blocked artery, flattening plaque buildup and allowing for normal function to continue.

Several years later, in 1986, a coronary stent was developed to hold open vessels and to attempt to lower restenosis rates in patients, which were around 30-40% of patients undergoing PTCA. Restenosis is clinically evident within the first 6-9 months after stent placement, and occurs in response to injury and inflammation due to the foreign body in the blood stream. Therefore, when implanting stents into the body became a normal procedure, restenosis rates became a concern for both patients and doctors.

In addition to restenosis, PTCA and stent implantation can cause exaggerated endothelial injury and inflammation, rendering both the stent and vessel highly thrombogenic. A fibrinogen layer covers the stent surface, further inducing platelet activation and thrombosis. Combining anti-platelet medication with stenting procedures is crucial in preventing local coronary thrombosis, myocardial infarction and death. Current recommendations for patients with bare-metal stents include dual anti-platelet therapy with aspirin and clopidogrel, which are continued for 6 weeks to allow complete endothelialization of stents. The incidence of myocardial infarction and death were significantly lower among patients who underwent surgery after their 6-week course of aspirin and clopidogrel were completed.8
**Drug-Eluting Stents**

In 2001, drug-eluting stents were introduced as a strategy to minimize restenosis and requirement for surgical re-intervention. The currently available polymer-coated stents contain antiproliferative agents which elute locally in the implanted coronary artery to prevent restenosis. (Figure 6) Initial animal studies demonstrated a clear benefit over bare metal stents (4-6% restenosis versus 20-30%), and early clinical trials further supported this. At present, 90% of all stents placed in the United States and Europe are drug eluting.

Despite the enthusiasm that resulted with the advent of drug eluting stents, incomplete endothelialization and stent thrombosis continue to plague these devices. Initial animal studies demonstrated complete endothelialization with BMS at 28 days, whereas drug eluting stents uniformly showed incomplete healing at 180 days. Based on early observations in both animal and human studies, it was recommended that patients with drug eluting stents receive dual anti-platelet therapy with aspirin and clopidogrel for at least 3-12 months, followed by life-long aspirin therapy, depending on the stent placed and the pre-existing co-morbidities which further increase the risk of stent thrombosis. Despite this regimen, late stent thrombosis remains a significant complication in patients with drug eluting stents. Late stent thrombosis carries a 45% mortality rate, usually through myocardial infarction or sudden death. Late stent thrombosis has been documented in both clinical and autopsy studies in patients as far as four years after stent insertion.\(^8\)
Biodegradable Stents

Bioabsorbable and biodegradable stents are designed in a similar way to traditional metal stents. The stent is helical in shape, with an inner core and exterior surface. The rates of degradation of the inner and outer cores are typically calibrated in such a way that the inner core degrades first, and the outer core will provide structure and support for a set period of time before degrading. The inner core can be made from a monomer from one of the following groups: lactide, glycolide, paradioxanone, caprolactone, and trimethylene carbonate, caprolactoe and blends and copolymers of these groups. The outer layer consists of a co-polymer of lactide and glycolide of varying consistencies. The inner core typically degrades by hydrolysis into smaller pieces that are filtered by the body, while the outer core degrades into a fibrillar morphological structure.
Although an improvement, biodegradable stents have some limitations. The overall strength and durability of the stents, when compared to traditional bare metal stents, is significantly lower. This causes the stents to need thicker support structures, limiting their usefulness in smaller vessels. The absorption rate can be so slow, that it leads restenosis. Since many are non-metallic, it is harder to see the stents while placing them within the body, and can lead to incorrect placement and force re-intervention.\(^\text{10}\)

**Expanded Uses**

Stents are designed to hold open any passageway in the body that, for one reason or another, has closed or partially closed. Although primarily used in cardiac treatment, stents have been utilized in the legs, urinary tract, and esophagus. Recently, researchers at Brown Medical School in Providence, R.I., have reported that stent placement should be considered the standard of care for treating patients with abnormal circulation, or "ischemia" to the legs, due to obstruction of the iliac arteries. The iliac arteries are large arteries in the pelvis that supply blood to the legs.

Lower-extremity ischemia, a type of peripheral vascular disease, occurs when arteries in the abdomen or pelvis, called the aorta and iliac arteries, respectively, narrow or become completely blocked by the build-up of atherosclerotic plaque deposits. As a result, not enough oxygen-rich blood gets to the legs, causing cramps and pain and making it difficult to walk or exercise. Rarely, the condition becomes so severe that gangrene develops or amputation of the affected limb is necessary. Until the introduction of the stent 10 years ago, the only way to open up such vessels was surgically, bypassing the blockage with a healthy vein or artery. Increasingly, interventional radiologists are treating the condition with a less invasive stenting
procedure, in which a catheter—or thin, flexible tube—is inserted through a small incision in the skin and threaded to the site of the blocked artery. The vessel is pumped open by a tiny balloon, and the stent is inserted to hold open the blood vessel.\textsuperscript{11}

**Minimally Invasive Surgery**

Minimally invasive surgery has advanced drastically in the medical field, providing a procedure that is less hazardous to patients. Four criteria make minimally invasive surgery significantly different than open heart surgery, including faster recovery period, smaller incisions, less damage to surrounding tissue, and most of the time no cardiopulmonary bypass machine. This procedure cannot be done for every heart disease because it is dependent on the location of the problem on the heart but it is usually done on the front of the heart and on coronary arteries.

There are many variations to minimally invasive surgery. This is so because the smaller incisions can be performed in many locations around the chest such as part of the breast bone, between the ribs, and underneath the sternum. (Figure 7) The flexibility of this procedure allows for more areas of the heart to be targeted. Typically, more than one incision is made so that tools can be used effectively by the surgeon. There have also been developments of robot-assisted surgery where the surgeon controls robotic arms holding the tools during the surgery.
The robotic arm approach allows for a less invasive surgery. The incisions made allow for only tools to go into the body with a robotic extension that surgeons can manipulate. This allows for surgeons to become more effective and capable for perform the surgery. Having the robotic aspect, the surgery involves even smaller incisions, more precision, and quicker healing times.

Risks and Benefits

The surgery, like any, has several risks involved. There may be some complications especially since the heart, most of the time, is still beating. The heart is still beating so that the risks involved with blood reentering the blood pathways and heart is non-existent. There will also be pain at the site of the incisions, which should not exceed more than 2-3 inches. Since the surgery is at the heart, there could still be risk of blood clots, blood loss, heart attack, strokes or infections.

The surgery is usually performed if there are one or two blockages typically in front of the heart. This type of surgery is very specialized because it takes a steady hand in order to perform the surgery effectively. The surgery can be complex and risky in the sense of performing the surgery through a small hole and a surgeon must have control or use the
robotic arm. This is especially important because the surgeon and the robotic arm must be able to navigate to the correct location of the blockage without damaging other tissues.

Minimally invasive surgery has less of a risk than open heart surgery even though at most times the heart is beating. The surgery results in less hospital time, saving money. The residual soreness will not be as great because there will be smaller incisions than for open heart surgery. Therefore, there is a lesser risk of clotting.

**Open Heart Surgery**

Traditional heart surgery involves making an incision that cuts through the length of the entire breast bone and requires a heart-lung machine. The heart is stopped and the blood is drained from the area. The heart-lung machine acts as a pump for the blood to flow through the body and helps the lung perform normally. After the operation has been completed, the surgeon allows flow of the blood to the heart in order to revive the heart and body. This type of surgery usually involves some type of grafting to the capillaries or arteries of the heart from another part of the body and can last upwards to 4 hours or more.\(^\text{14}\)

**Risks and Benefits**

As mentioned above for any type of surgery, there are certain risks. With draining the heart of blood, there is risk of complications such as clotting as the blood is flowing back into the heart. Also, there is a risk of a stroke and potentially memory problems. Breaking the entire sternum can cause some problems as well. Opening the chest has quite a bit of recovery time since the whole bone is split. There is especially more risk for infection through an open heart surgery because the size of the incision. There will definitely be chest pain present as well as a longer stay in the hospital and recovery time that can range from a few weeks to a few
months. Figure 8 compares the different incisions between a traditional open heart surgery and those made in a robotic minimally invasive surgery (MIS).

![Image](image.png)

Figure 8: Open Heart Surgery incision (left) compared to incisions made with robotic MIS

The heart-lung machine provides support for the heart and the lungs during the surgery. There is not blood flowing through the heart until it flows back through. Though the heart does need the blood and oxygen to pump, the length of time the heart is without it could cause some lung failure or heart rhythm problems.

**Patient Perspective**

Some religious beliefs conflict with current medical practices. Parents who are set in their beliefs can sometimes prevent treatment for both themselves and their children. There have been many cases over the years of parents being charged with the deaths of their children by refusing to take them to the doctor. Two of the largest dominations that are in favor of prayer over treatment are the Church of Christ and Jehovah’s Witnesses.

The Church of Christ promotes healing of physical and mental illnesses through prayer. Recently they have begun to compromise when dealing with broken bones, allowing members
to have their bones set by a doctor and then returning to prayer. However, many Christian Scientists object to medicine and doctors as a whole, for both themselves and their children. The majority of their beliefs are based on the New Testament, where Jesus was documented as healing the sick through prayer.¹⁷

Jehovah’s Witnesses are a religious group that has interpreted several passages of the Bible to mean that they must refuse blood transfusions, even in the face of death. According to Jehovah’s Witnesses, any member that willingly accepts a blood transfusion is committing a sin. In the case of a simple medical procedure, such as a stent implementation, this might not be an issue. However, for more invasive open heart surgery, blood transfusions are necessary.¹⁸

**Comparison of Treatments**

For patients with stenosis

- 50% undergo angioplasty
- 20% undergo a stenting procedure
  - 90% of those stents are drug eluting
- Every patient is put on some kind of medication
  - Medicines used to treat CHD include anticoagulants, aspirin and other anticlotting medicines; ACE inhibitors; beta blockers; calcium channel blockers; nitroglycerin; glycoprotein IIb-IIIa; statins; and fish oil and other supplements high in omega-3 fatty acids.
- Risk
  - Angioplasty has less than 1% chance of death¹⁹
    - Requires about a day or less of hospitalization after procedure
    - Catheter can cause bleeding or damage blood vessels; dye used could cause allergic reaction -> kidney problems²⁰
  - Likeliness of restenosis – 20-30%
Emergency bypass surgery is around - 2%

Stent risk

- Blood clots can form around the stent (1-2% of patients)
  - The highest in the first few months of the stent being placed
  - Risk is reduced by anti-clotting drugs and anti-coagulants.
- Likeliness of restenosis after stent is about 20% on average
  - 4-5% for drug eluting stents and around 40% for bare metal stents that properly heal

Minimally invasive surgery

- Requires less time in hospital than open heart surgery.
- There is a greater learning curve for surgeons to perform minimally invasive surgery over open heart surgery
  - The small incisions don’t leave much room for movement so preciseness is necessary

Open heart surgery

- Risks - stroke, heart attack, graft failure, death (3 out of 100 procedures), bleeding

Grafting

- Saphenous vein graft vs internal-mammary-artery graft to the anterior descending coronary artery alone or combined with one or more saphenous-vein grafts
- Patients who had only vein grafts had a 1.6 times greater risk of death throughout the 10 years, as compared with those who received an internal-mammary-artery graft.
- In addition, patients who received only vein grafts had 1.41 times the risk of late myocardial infarction, 1.25 times the risk of hospitalization for cardiac events, 2.00 times the risk of cardiac reoperation, and 1.27 times the risk of all late cardiac events, as compared with patients who received internal-mammary-artery grafts.
The Future of Intervention

Initially, when a patient requires intervention to hopefully prevent future heart conditions, the mechanical support that a stent provides allows for more complete healing of the arterial walls. However, beyond the first few months the mechanical support is no longer required. However, if a stent is placed properly and proper healing takes place, it is virtually impossible to remove that stent. The scientific community has begun to take an interest in bio-absorbable stents, due to their potential in reducing common risk factors of traditional stents. One of the main arguments in favor of developing a bio-absorbable stent is due to the progression of restenosis, which can be found even seven to ten years after a stent has been implemented due to lack of endothelization. There have been several successful trials in humans of bio-absorbable stents; however none are currently available for commercial use. The stents that are currently in trials have a wide range of both mechanical properties as well as materials that go into the stent make-up. Theoretically, this type of stent could dramatically alter the way that doctors approach medical procedures. These stents would allow for repeated re-intervention and potentially less long-term health complications for the patient.24
Conclusion and Recommendations

Currently, a bare metal stent with a closed cell structure is the most beneficial answer to stenosis for the patient. Bare metal stents have a more consistent healing time than drug eluting stents, which allow for more accurate predictions of both restenosis and thrombosis. The chemical make-up of drug eluting stents does not provide the patient with an overall safer healing process due to the problems that are most commonly associated with stents, namely late stent thrombosis. Studies have shown that bare metal stents have a higher endothelization rate than other stents, meaning that they are a safer statistical option than other stents on the market. Additionally, if incomplete endothelization does occur, the mechanical properties of bare metal stents, namely the metallic structure, allow doctors to view the stent without surgery and predict potential complications in the stent, helping to alleviate patient concerns about unpredictable late stent thrombosis.

A stent is not a magic solution for every cardiac issue. They are most effective when paired with the appropriate drugs that prevent the body’s natural defense mechanisms from inadvertently causing the patient harm. Without proper monitoring by doctors, patients will return to the hospital with the same complications as before, or even potentially worse health issues. Stenting is a preventative measure that should be used with caution in order to provide the most benefit to the greatest number of patients.

In the future, hopefully, medical technology will have progressed for enough to allow for bio-absorbable stents becoming a reality for all patients. Scientists should strive to create a material that allows for a smooth transition for doctors. This material could be used to create a stent that remains in the body for long enough to provide the initial mechanical support
necessary, but will slowly be absorbed by the body and either eliminated as waste or utilized in some other function. This type of stent would eliminate life-long drug therapy, reducing long-term side effects on the patient body.
References


Appendices

Appendix A- Proposal

Original Proposal

As the life-span of humans continues to grow, doctors are being forced to deal with more patients with more complex medical issues. Many patients are not aware of all of the surgical paths that they can take, and as a result patient care can decline. Our primary focus is on the issues surrounding the health of the heart and the lack of general knowledge about the heart. Patients need to become more aware of the potential surgical options and the issues that are associated with each route. Surgical solutions can be very costly, and patients can be duped into undergoing procedures that are unnecessary and overly costly when compared to other solutions.

In order to most effectively raise patient awareness about not only surgical procedures but the costs associated with each procedure, we will perform a literature review of scholarly articles as well as patents for stents. We will also conduct interviews of both professors familiar with stents, and doctors in the cardiac field.

The final result of our paper will be a comprehensive look at the heart itself, and some of the causes of heart malfunction that result in medical complications. In order to clearly discuss the different types of surgical solutions, we will discuss the evolution of heart surgery and the newer medical procedures, such as stents, that are available for patient use. We will discuss not only stents that surround the heart, but how stents could be used in other areas of the body. From there, we can evaluate the pros and cons of stent use and the role that stents play in the surgical arena. Also discussed, will be the different surgical solutions that can be paired with
stents. The possible future role of stents, including biodegradable stents will be examined, along with a look into the future of cardiac surgery. After evaluating the uses and roles of stents, it will be possible to evaluate comparative costs or each procedure and how one choice can impact future medical and financial decisions of the patient.

From our comprehensive comparison analysis, we will be able to accurately evaluate what type of procedure is best for the patient and present our finding in a clear and succinct format. The patient can use our report to assist in the decision making process before choosing a surgical path.
Appendix B - Interview

Professor Satya Shivkumar Interview Notes

- Drug eluding stents peaked in 2007
  - Market value was at 5 billion and is now at 2.5 billion
  - Now in decline because of problems that arose
    - Was supposed to minimize restenosis but actually accelerated it
    - Narrowing of the blood vessel leading to restricted blood flow
- Stents require a medication for blood thinning.
- Drug encased in a polymer coating on a stent
  - Drug effects surface properties of the metal (polarity, etc.): therefore it was less effective than bare metal stents
  - Process to put the drug onto the metal affected the patency rate
    - Likelihood that the vessel will stay open
  - The drug, paclitaxel, was not the problem; it was the encasing changing properties.
- Surgeons are reluctant to change and about 70-80% of stents used in surgery are actually stainless steel/metal stents
- The release of drugs to the blood stream is through gradual diffusion over time.
  - Initial release is a decent amount and then the rate gradually goes down
- The drug used, paclitaxel, is also a drug used in cancer treatments
  - It blocks the blood supply to the cancer cell to prevent internal layers of the wall
    - Minimizes inflammation
  - Good short term but not so good long term
    - Depends on the person
- Stents are usually a permanent fix and it should not be done repeatedly
- People still are doing research into drug eluting stents but the research is progressively slowing down due to poor results
  - Drugs may be different. Dependent on the mechanic properties of the tissues and stents
- Biodegradable stents
  - Not as supportive as the metal stent which is a good thing to the tissue surrounding the stent
    - The support may make the rest of the capillary weaker, therefore the possibility of more stents increases
  - The stent is in for the length of time it is needed and then will no longer be a potential hazard
    - Variable to the amount of time it is necessary a person needs it