The Cost Variations in Total Hip and Knee Implant Surgeries Across and Within Two Portuguese Hospitals

by

Mónica von Schoeppen Álvares Ribeiro

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Supervised by

Professora Doutora Susana Maria Sampaio Pacheco Pereira de Oliveira

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Biographical Note

Mónica von Schoeppen Álvares Ribeiro was born in the city of Oporto, in Portugal, on the 15th of December of 1989.

The candidate graduated in Business Management at the Portuguese Catholic University, in Porto in January of 2011, with an average final grade of 14 out of 20 points. During this period, she attended an exchange program under the Erasmus program in Università Commerciale Luigi Bocconi, Italy.

Between February and July of 2012 the candidate did an internship at the Arkansas Heart Hospital, USA, in Hospital Management.

In 2012 she enrolled in the Master in Management, at the University of Porto, Faculty of Economics, finishing the academic part in January 2014, with an average final grade of 17,2 out of 20 points.

Between April and December of 2014, she did a Professional Internship at Sonae, in Finance and Accounting.

At the moment she is a Helen Doron English Learning Centre Franchisee in Maia, an international brand present in 30 countries.
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Abstract

The demand for total hip and knee surgeries, in Portugal, has a large potential to increase in the future, since Portuguese population is ageing quickly and the proportion of those who suffer from obesity is also increasing. Both of these are the strongest risk factors affecting the need for these types of surgeries.

The main aim of this study is to identify the cost variations in total hip and knee implant surgeries, both across and within two Portuguese hospitals, one public and one private, and to identify the factors with most impact on costs.

Hip and knee surgeries in Portugal are costly, involve many actors and therefore many potential conflicts of interest. We tried to identify some areas where there is wastage of resources so that these resources may be used for other things within this sector.

To our knowledge, there are no similar studies done in Portugal and due to the adverse financial situation, which Portugal is still facing, and the fact that the health care sector represents a very large percentage of the Portuguese GDP the increase in efficiency assumes now an even greater importance.

Also, it might be useful for managers in this sector to know where they may cut costs and save resources to be applied elsewhere, since hip and knee surgeries are costly and present potential to become less.

We generated information from both a public and private hospital through the analysis of patients’ records, of those that were put through a surgical procedure for hip or knee implants and the costs for the organization. We also gathered and compared information on the Hospitals’ rules on implant choices.

Keywords: Total hip replacement surgery, Total knee replacement surgery, Costs, Physician Preferred Items, Portugal
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1 Introduction

1.1 Motivation and Objectives

Since my undergraduate degree in management I have developed a strong interest in the area of hospital management. This interest grew quickly into a passion after doing a rotational internship, for six months, at the Arkansas Heart Hospital in the USA. Being aware of the unfortunate economic situation in Portugal and the importance of always reducing costs to insure the sustainability of any organization, I decided to choose an area which has high impact on the improvement of the Portuguese population’s quality of life and which is predicted to grow even more, consumes a large amount of resources and on which very few studies are published. For these reasons I chose to study and analyse the costs associated to hip and knee replacement surgeries.

Studies analysing and comparing costs in hip and knee surgeries both across and within different hospitals are common in the United States of America, presenting great importance in terms of hospital management. In Portugal, to our knowledge, there are no studies about these questions even though they seem to be very relevant in terms of resource optimization and in generating hospital efficiency.

To conduct this thesis we gained knowledge through direct and indirect observation in two Portuguese hospitals in the city of Porto. We collected data on hip and knee surgeries and interviewed professionals working in this area: doctors, nurses and hospital administrators. We then formed two research questions that will be presented below, which we try to answer throughout this work through the evaluation of qualitative and quantitative analysis. In addition we confront our analysis with what is presented in the literature review.

For these reasons we believe that this thesis is original and will have a large contribution for students with interest in this area, for Portuguese managers and also for the country.
The aim of this study is to identify and compare the cost variations in total hip and knee implants, both across and within a public and a private hospital, in Porto. We will also explore possible ways to achieve cost reductions through a better understanding of what really impacts costs and how implants are managed, especially in terms of the selection process.

It is important to explain that the study will be done from the Hospital’s perspective and therefore we will compare the costs for each hospital.

We intend to do this with the collaboration of two hospitals which perform a high and significant number of hip and knee surgeries and which are interested in what our study offers. We will access patients’ information and analyse all costs, which contributed to the final cost that the hospital had with each patient they treated. These costs will include expenses with staff (doctors, nurses, and administration), hospital equipment, implant price, patient’s length of stay (in days) and medication. We will try to understand how differences in the price of the implants, patient characteristics and the amount of resources used affect the final cost, per patient, for the hospital. This will help us understand the real reasons among existing cost differences within and between both hospitals.

With the combination of this information we will then be able to understand where there is space for further improvements and will suggest possible cost reductions.

1.2 Historical Evolution of Hip and Knee Replacement in Portugal and Other Countries

The hip is a ball and socket joint, where the upper end of the thighbone (femur) meets the pelvis. The femur has a rounded cup-shape at the end, which fits into the pelvis’ cavity – the acetabulum. Both the ball and socket are covered with cartilage layers and in between these there are synovial membranes that release synovial fluid to lubricate the joint. This not only allows for a smooth glide between both, but also works as a shock absorber. They are held together by ligaments and by the hip’s muscles. This
joint is very important for our body since it bears with our weight and the force between our hip and knee muscles and allows us to move in a large range of motion. In the case of damaged or worn parts of the hip joint, which lead to pain because the surfaces become rough, movement becomes limited. The hip replacement surgery replaces the damaged parts with an artificial joint: a cup and ball made out of metal and strong plastic. The metal surface is porous which lets the bone grow into it healing tightly. The causes for a worn hip joint may be aging, injury, arthritis or a side effect from certain medicine. During recovery it is normal that the patient has some pain and time is needed for muscles to recover. During this phase physiotherapy is considered to be very important for correct healing (Foran, 2011).

The knee is composed by three bones; the lower end of the thighbone (femur), the upper end of the shinbone (tibia) and the kneecap (patella). These are covered with cartilage, which protects and permits smooth movement between the bones. The femur and tibia are held in place by ligaments, which also provide stability, and between these two bones are the menisci, which act as shock absorbers. The synovial membrane covers the remaining surfaces. This membrane releases the fluid that lubricates the cartilage, which is very important to reduce friction. With disease or injury these components stop working correctly causing pain and therefore limiting movement. Osteoarthritis (wearing of the cartilage due to obesity, injury or overuse), rheumatoid arthritis (inflammation and thickening of the synovial fluid), and post-traumatic arthritis (subsequent to knee injury) are the main causes for this. A knee replacement surgery is the replacement of the surface of the bones, where damaged cartilage and the underlying bone are removed and the femur and tibia ends are replaced with metal components, the under surface of patella, if necessary, can be cut and substituted with a plastic button and finally a plastic spacer is introduced in order to permit smooth gliding between the metal components (Foran, 2011).

Hip and knee replacement surgeries are very effective in reducing pain and disability in patients with osteoarthritis disease and are also used with patients with hip fractures. Osteoarthritis is one of the most disabiling diseases in developed countries. As we have seen before, age is the strongest risk factor for the development of osteoarthritis. Other factors are obesity, physical inactivity, smoking, excess alcohol and injuries. This
disease is more prevalent in women (18%) than in men (10%) and in people over their 60s (OECD, 2014).

In terms of age, more people with 65 years and over undergo a hip arthroplasty in Portugal than those aged under 65. In 2011, 18% more of hip arthroplasties were done to patients with 65 years of age or older than to patients under 65 (Pabinger and Geissler, 2014).

In terms of gender, we found a study on osteoporotic hip fractures, in Portugal, which shows us that between 2000 and 2008 the incidence of hip fractures is around 70% higher in women than in men. With regards to age, the average in men was of 78 years and in women of 81 years between 2000 and 2008 (Alves et al., 2013).

In Portugal, in 2008, once again total knee surgery in women was much higher than in men. The first presented a value of 73% and the latter the remaining 27%. In terms of age the same pattern maintained; people aged over 65 years presented 72% of those undergoing a total knee surgery (Kurtz et al., 2011).

The number of hip and knee surgeries has been increasing rapidly in most OECD countries. As we can see from graphs Graph 1: Total Knee Replacement Surgery and Graph 2: Total Hip Replacement Surgery, the average increase in hip surgeries and knee surgeries between the year 2000 and 2011 have been of 29% and 94%. In Portugal’s case, hip and knee replacement surgeries, in public hospitals, have increased by 22% and by 239% respectively between 2000 and 2009. Even though there are more hip replacement surgeries than knee, the trend shows us a much faster increase occurred in the latter one (OECD, 2014).

In Spain, the increase of hip and knee surgeries, between 2004 and 2012, has been of 24% and 40% and in the United Kingdom, between 2005 and 2012, it has been of 23% and 25% (OECD, 2014).

In the US, total hip and knee surgery, present some of the highest volume surgical procedures and constitute the largest hospital expenditure category for Medicare (Robinson and Dolan, 2008), which is responsible for the elders. Demand has been
rising from year to year. Between 2000 and 2010 there was a 100% increase in hip replacements and a 102% increase in knee replacements (OECD, 2014). Procedure volumes continue to grow as the population ages and indications are that it is expected to include younger and more active patients (Robinson et al., 2012).

By 2030 the demand for primary and revision hip replacements, in the US, is projected to more than double, while the demand for primary and revision knee replacements is projected to increase more than 600% (Wilson et al., 2008).
1.3 The Importance of Total Hip and Knee Surgeries and Future Expectations about the Evolution of the Demand for the Implants

Demand for hip and knee replacement surgeries is increasing and will continue to increase exponentially in the future in developed countries (Wilson et al., 2008) due to
population ageing and an increase in obesity problems. Both factors have a strong impact on the need for these types of surgeries.

Portugal presents no exception to these trends. Life expectancy and obesity rates among the Portuguese population have been increasing. Life expectancy at birth increased from 74.1 years to 80.6 between 1990 and 2012, presenting a faster pace than the EU-28 average, which increased from 74.1 to 79.2 years. Life expectancy at the age of 65 increased by 5.2 years for men and by 6.8 for women between 1960 and 2012 in Portugal; once again above the EU-28 average. In 2012 it was of 17.6 years for men, of which 7.8 were healthy years, and 21.3 for women, of which 6.3 years were healthy years. The number of healthy years is below the EU-28 average (8.5 years for men and 8.7 for women) (OECD, 2014). The trend, in the share of population aged over 65 and over 80 in Portugal, is an increase from 18% in 2010 up to 32% in 2050 and from 5% up to 11% respectively (OECD, 2013). Population ageing will put pressure on health care systems, since more people will need to receive extra medical care, and on their financing, as the amount of active population will decrease.

In terms of overweight and obesity, Portugal presents a very negative scenario. In 2012 15.4 % of the Portuguese population, aged 15 years and over, suffered from obesity. This problem has been increasing gradually since the year 2000 (3.9%) and affects more women than men (OECD, 2014). Overweight and obesity among children has also been increasing. For 15 year olds, between 2001 and 2006, the increases were from 15.1% to 22% in boys and from 6.4% to 13% in girls. In 2010, children from various ages had excess weight rates of 27% for boys and 29% for girls. This may be a problem for the future, because childhood is a very important period for children to create healthy habits, from which they may benefit in the long-term. Children who suffer from overweight are at more risk of having poor health during their adolescence and adulthood, than those who aren’t. They have an increased risk of being obese adults, suffering from osteoarthritis, diabetes and many other forms of diseases or even dying prematurely (OECD, 2013).
With the increase both in life expectancy and in overweight, osteoarthritis disease has a large potential to also increase. This disease is a joint disorder; it is the wearing and tearing of a joint, caused by ageing, which leads to pain and limits movement and therefore creates the need for a hip or knee surgery. Overweight increases the risk of having osteoarthritis since more weight causes even more wearing and tearing of the joint (Dugdale and Zieve, 2013).

For theses reasons we believe that future demand for hip and knee surgeries in Portugal will increase which makes these types of surgeries of great relevance for our hospitals.

Apart from these two main risk factors, other important factors are: bone density, bone morphology, meniscal derangement, gender, sex hormones, and trauma (Carr et al., 2012).

Another interesting point, which has been largely researched on, is supplier-induced demand. This happens when doctors influence patient’s demand for medical services, acting intentionally against what is of best interest for the patient. That is, they use their superior information to change demand for medical services in their own benefit. The physician, acting as the patient’s agent, produces a different level of demand than the one the patient would have chosen if he had the same information as the physician (Bickerdyke et al., 2002). Besides that, physicians have preference over some implants due to many aspects, such as their experience in terms of final results, type of technique used for each implant, type of material the implant is made from, characteristics of patients they normally have and the brand of the implants used during their training years. For this reason they have an opinion when it comes to choosing which implants the hospital will buy. So implants are called Physician Preference Items.

1.4 Structure of the Following Chapters

Besides this section, this thesis is structured as follows: in Section 2 an analysis of the medical device market is done in order to put us in context of what is happening in
European countries and especially in Portugal. In Section 3, a literature review of the topic is made. In section 3.1 an extensive analysis of similar studies and their main results are addressed and resumed through the use of tables, in order to help us understand the context and relevance of this thesis. In section 3.2 a critical analysis of the reviewed literature is done. Then, in section 3.3, methodological aspects of similar studies and of our research are explained. After, in section 4 we present the formulation and explanation of our research questions. In section 5 we focus on the methodology of our study through the characterization of the hospitals and patients, the way we conducted our interviews and the software used to analyse all the data we gathered. In section 6, after a descriptive analysis of our data, we present the results of the statistical method and a summary of the interviews and discuss them using the proposed research questions. Finally, in the last section we discuss the main results against the studies and theories of other authors, their implications for managers and decision makers, investigation limitations and we also make recommendations for future investigation.
2 Context: The Medical Device Market

Since our work analyses the costs hospitals have with hip and knee implants it is important to understand how the medical device market works in Portugal and therefore we did some research on this topic.

The economic recession in Europe impacted negatively the medical device market and between 2010 and 2011 overall growth was of only 2.7%. Portugal and Greece were the countries which were most affected (Ken Research, 2014).

Nevertheless, due to the growing demand for medical devices, this market has gone through continuous growth and is estimated to grow at a Compound Annual Growth Rate (CAGR) of 3.9% between 2013 and 2018. This is a consequence of population ageing, conscious and better-informed patients, increasing demand for innovative medical devices and access to improved technology (Ken Research, 2014).

The medical device products include patient aids, consumables, diagnostic imaging, dental products, orthopaedics and prosthetics, respiratory devices and ophthalmic devices (Espicom Business Intelligence Ltd, 2014). These products are generally manufactured in Germany, France, the UK, Italy and Spain (Ken Research, 2014).

The Portuguese market is one of the smallest in Western Europe as well as per capita spending, an estimated of 92 US dollars in 2013. The public sector is responsible for most of the market and in 2013 it established a 15% reduction in medical device prices (Espicom Business Intelligence Ltd, 2014).

In 2014, not only were medical device companies having great difficulties to survive in a slow moving market of lower purchasing volume and prices, but also to hold on as the public sector owed them around 929 million US dollars (Espicom Business Intelligence Ltd, 2014).

The Portuguese market imports greatly from other European countries. Portugal had a negative medical technology trade balance in 2012 of around 4 hundred million Euros
(MedTech Europe, 2013). Between the second half of 2013 and the first six months of 2014 this value increased; imports reached around 856 million dollars and exports around 321 million dollars. Some products registered an increase in the imports, but orthopaedic and prosthetics registered a decrease at around 3.5% (Espicom Business Intelligence Ltd, 2014).

The Portuguese medical device market is estimated to have a compound annual growth rate at around 2% until 2018 (Espicom Business Intelligence Ltd, 2014).
3 Literature Review

3.1 Similar studies

Now we will present the main results and contributions of similar studies, which have been analysed in terms of demand and costs for total hip and knee surgeries and how hip and knee implants, being Physician Preference Items (PPIs), impact costs. The majority of the studies were conducted in the United States of America (US) and a few in Finland, Sweden and the United Kingdom. In Portugal, the majority of studies found are about demand and one addresses the total length of stay and complications in total knee surgeries and none are related to costs.

Surgical complications are any deviation from the normal postoperative course and vary in terms of level of severity (Dindo and Clavien, 2008). Complications from hip and knee surgeries can take the following forms: heart attack, stroke, thrombosis, joint infection, blood clots, leg-length inequality, dislocation, loosening and implant wear, nerve and blood vessel injury, bleeding, fracture, and stiffness (Ma, 2014).

It is also important to refer that total knee surgeries are highly successful, as it relieves pain and improves knee function and therefore another reason for an expected increase in demand for these surgeries in the future is that they are being increasingly considered for patients younger than 55 years (Carr et al., 2012). This trend is taking place in the United States, Sweden and Australia. The possible reasons for this are the fact that surgeons and patients expect durability for the reconstructed knee, quality of life that compensates the potential for early revision surgery (Keeney et al., 2010), increase in the incidence of knee osteoarthritis in the younger population, increase in the grade of severity, broadening of the indications for surgery due to a greater level of confidence from the surgeons in the surgical treatment (W-Dahl et al., 2010).

With this information, with an increase in the ageing population and people suffering from obesity problems, we know that Portugal is increasingly facing the two biggest risk factors, which strongly affect the potential need for total hip and knee surgeries.
In terms of cost analysis, we found out, in ‘Device Costs, Total Costs, and Other Characteristics of Knee Replacement Surgery in California Hospitals, 2008’, a study done by the Berkeley Center for Health Technology, that in Californian Hospitals the variation in total hip and knee surgery costs vary by a factor of three and these exist both across and within hospitals. Therefore total costs may be lowered both internally (reduction of errors, finding cost savings) and externally (suppliers’ power). We are going to use this study as a guide for our work in two Portuguese hospitals, for both hip and knee.

Implant device costs present large variability. In the US, the average knee implant cost per case ranges from $1,797 to $12,093 and from $2,392 to $12,651 for total hip replacement procedures. Both knee and hip implants vary across and within hospitals, even after controlling for patient diagnosis and comorbidities (Robinson et al., 2012).

It is also important to refer that the average selling prices of these implants have been increasing by more than 100% in the last 10 years and the same product may vary between $2,000 and $9,000 (Montegomery and Schneller, 2007). This shows how much power implant vendors have, especially because hospitals in California buy 70% of their devices from only two vendors, when there are at least five in the national market (Robinson et al., 2012). This increases vendors’ bargaining power, leading to the lock-in dilemma for hospitals (Robinson and Dolan, 2008) as they find themselves in a situation with high switching costs.

To better understand this, it is very important that we comprehend the concepts of “Lock in” dilemma and “Switching costs”.

The “Lock in” dilemma happens when for all intent and purposes, one party is heavily dependent upon the other party, with few alternatives (Narasimhan et al., 2009). This is very important when understanding hospitals’ relationships with implant sellers, especially when hospitals only use one or two sellers from the market, doctors adopt a specific technology and when they want to change switching costs are so high, that it is very expensive to make those changes.
“Switching costs” are incurred when the purchasing organization changes suppliers. For physicians these assume great importance, in the case that they have to change the supplier of the implants that are being used for hip and knee surgeries, since the physician will need time to adapt and learn how to use the new implant and its related instruments. Switching costs may also impact hospitals as there may be substantial administrative time allocated to establishing a new contractual relationship with new vendors (Robinson and Dolan, 2008).

In 2011, hip and knee replacement surgeries in European countries have both an average price of 6 800 € (OECD, 2014).

In Portugal, according to four different severity levels, the total price for hip surgery, in public hospitals, can vary between 3 737 € and 17 680 € and length of stay varies between 10,87 days and 47,48 days. In the case of knee surgery, total price varies between 3 649 € and 13 949 € and length of stay varies between 8,16 days and 23,85 days (Diário da República, Portaria n. º 234/2015, 2015).

There is also significant variation in surgical complications across the Californian hospitals ranging from 0% to 33% and patients’ length of stay varying from 2.4 to 6 days. Both have impact on hospital costs (Robinson and Dolan, 2008).

In one of the studies, implant cost variations were attributed to three different things: patient characteristics (age, diagnoses, comorbidities, complications, discharge destination, insurance coverage vs. Medicare), hospital characteristics (number of beds, annual procedure volume, teaching status) and within hospital variation (physician specific preferences in terms of device choice, differences in the price charged by different manufacturers). For total knee replacement, only 2.5% of total variation in device costs was attributable to patient characteristics, 61.0% was attributable to hospital characteristics and the remaining 36.5% of variance was attributable to within-hospital variation. For total hip replacement, 4.4% of variance was attributed to patient characteristics, 36.1% was attributed to hospital characteristics and 59.5% was attributed to within-hospital variation (Robinson et al., 2012).
It is suggested that this variation within hospitals might be the result of differences among surgeons in their preferences concerning device brand and functional level (Robinson and Dolan, 2008).

Relating to this study, hip and knee implants are considered physician preference items and therefore will be one of the targets of our study, since these have a big impact on hospital costs and doctors’ opinions have a large weight when it comes to buying the implants (Robinson and Dolan, 2008). It is important to clarify that “Physician Preference Items” are medical devices and equipment that is selected by physicians for their patients. These are normally chosen based on physicians’ familiarity or loyalty to the brand and are usually very expensive (Wilson et al., 2008; Robinson and Dolan, 2008).

Hospital supply costs are rising dramatically, with Physician Preference Items representing a big part (Montegomery and Schneller, 2007). These represent a lucrative cost-cutting opportunity (Tyson, 2010).

There is a growing gap between costs and reimbursements for procedures using physician preference items and these can represent between 40% and 80% of the procedure's total cost (Tyson, 2010). Also, payers pay high prices and lack input on the choice of implants (Wilson et al., 2008).

Knee and hip implants are physician preference items (PPIs) and this has resulted in conflicts between surgeons and the hospital administration (Robinson and Dolan, 2008).

Hospitals have tried to work on this issue of how to manage better PPIs. In the US, they have tried to change their relationship with the surgeons through a better coordination of their decisions, rather than through dictation. They have worked towards building an environment of mutual trust and respect, where both actors are committed to a common goal of cost reduction and patient safety (Montegomery and Schneller, 2007).
Furthermore, it is suggested that standards for product choice of PPIs should be created, since there are no consistent national standards or programs to influence product choice of PPIs. In the United Kingdom, the National Institute for Health and Care Excellence sponsored a study which shows that more than fifty different prostheses were being used, but only seven of these implants showed good results and only four of these seven were being used in the National Health Service (Montgomery and Schneller, 2007).

There are many strategies that have been proposed to reduce PPI costs. Tyson (2010) presents a summary of the main ones. Firstly, using benchmarks, measuring results and implementing monitoring tools are very important for sustained improvements in terms of costs, quality and productivity. Secondly, it is very important that the hospital ensures that they are getting the best price possible on implants and other high-cost items and negotiates with different vendors, in order to have the power of choosing and preventing the lock-in dilemma. Furthermore, employing lean and Six Sigma methodologies to reduce costs, enhance quality, and optimize productivity is very useful. Finally, physicians are the key to controlling and reducing the hospital's costs for PPIs, since they may easily identify cost-saving opportunities as they are working directly with the patients and choosing the devices to use in surgery. Teaming up with them is very useful, but engaging them takes much more than only talking about money (Tyson, 2010).

These conflicts will subsist whilst physicians feel that the efforts done by hospitals are motivated by the concern with controlling costs at the expense of high-quality patient care.

It will also be very difficult to control the relationship between suppliers and orthopaedic surgeons, since suppliers search for and use surgeons for product development (Wilson et al., 2008).

To conclude, the choice of hip or knee implants are considered a point of conflict between doctors and administration and therefore many strategies were studied and proposed to diminish this problem. Involving physicians in this process is the most popular suggestion.
A study on the effectiveness of hip or knee replacement surgery in terms of quality-adjusted life years and costs was conducted in Finland to 223 patients who enrolled for these surgeries.

“Quality Adjusted life years” (QALY) is a measure of the quantity and quality of life a patient has after going through an intervention. It is a way to assess and compare the benefits (quality of life and/or survival) gained from medical interventions. Health states are measured in the following way: perfect health = 1 year, less than perfect is less than 1 and higher than 0 years, death = 0 and someone who is in a terrible health state receives a negative score. These scores can be combined with the corresponding costs, in order to reach cost-utility ratios. These indicate the additional costs to achieve 1 quality adjusted life year. This allows for comparisons between interventions. Knowing the cost per QALY gives hospitals the opportunity to establish priorities and understand which interventions have the largest benefits in terms of health (life expectancy versus quality remaining years) and costs (Phillips and Thompson, 2009).

The patients from the study done in Finland were asked to fill in a 15-dimension health-related quality of life (HRQoL) survey before and after operation. There were statistically significant improvements in moving, usual activities, discomfort and symptoms, distress, and vitality. During a 1-year period, the mean cost per QALY gained, calculated using the incremental cost-utility ratio, which is the difference between the costs of two interventions divided by the difference in the QALYs they produce (Phillips and Thompson, 2009), was twice as higher from a primary knee replacement (13 995 €) than that gained from a primary hip replacement (6 710 €), but it was even higher for a revision hip replacement (52 274 €). Furthermore, the factors that impacted these gains were in terms of age, since being younger brings greater gains, and in terms of waiting time; the less you waited the bigger the gains (Räsänen et al., 2007).

From these studies, we can conclude that in the USA variations occur within and across hospitals in terms of device costs, total costs, surgical complications and length of stay. The factors affecting this are variations in hospital characteristics, patient characteristics and physician preferences on implant choices.
In addition, physician preferred items represent a large part in hospital supply costs and reimbursements for surgeries with these items have been decreasing.

Finally, we also saw that, in Finland, hip and knee surgeries bring gains in terms of quality adjusted life years (QALY) and how less age and waiting times positively impact gains.

3.2 Critical analysis of the literature reviewed

As we have seen in previous studies, in the US and in Portugal, demand for total hip and knee surgeries has been increasing, even though in different rates, at least since the 90s and is predicted to increase even further due to the two main risk factors: the aging of population and the obesity epidemic in developed countries. We can see that the majority of these types of surgeries are done to people aged above 65 and to a larger extent to women. These surgeries are very successful in decreasing pain and in increasing mobility and therefore contribute greatly for the population’s well being.

In terms of costs, for these types of surgeries, we can say that there are great variances both across and within hospitals, in the US. This is an indication, that there is still space for cost reductions.

Physician preference items present two main problems. In terms of their costs, these have been increasing and there are large variations between the prices of the same type of implants. In addition, they are the main reason for conflicts between the involved actors, since it is believed that the variation in device costs within hospitals is provoked by surgeons’ preferences. For this reason it is defended that to work towards cost reduction surgeons should be included in the process of choosing and negotiating for implants, together with the management team. Other very interesting strategies for the reduction of implant costs are explored and include the use of benchmarking, negotiating with different vendors and using lean and six sigma methodologies.

The main methodological aspects and conclusions of the similar studies, above discussed, are summarized and presented in Table 1: Methodology and Conclusions.
<table>
<thead>
<tr>
<th>Authors and Year of Study</th>
<th>Country of Study</th>
<th>Sample Size</th>
<th>Data Collection</th>
<th>Statistical Analysis</th>
<th>Main Conclusions</th>
</tr>
</thead>
</table>
| Räsänen et al. (2007)    | Finland         | 223 patients | Survey on health related quality of life in a trial involving several thousand patients from 10 medical specialties. Surveys were answered before and after surgery. | Multivariate statistical analysis (using SPSS) | – Both hip and knee replacement improve health related quality of life.  
– The cost per QALY gained from knee replacement is twice that gained from hip replacement |
| Montgomery and Schneller. (2007) | USA | 25 people from 4 hospitals | Interviews (60 – 90 minutes) on knowledgeable people from different levels who had first-hand information and experience. Attended meetings of two major group-purchasing organizations. | Qualitative Analysis | – Costs can be reduced through PPI management  
– How to better manage PPIs |
| Wilson et al. (2008)     | USA             | Analysis of the issues, relationships, emerging hospital strategies and policy needs surrounding hip and knee implants. | | | – Demand for hip and knee replacements is rising annually  
– Costs are high  
– Implants are normally chosen based on physicians’ familiarity or loyalty to the brand |
| Robinson and Dolan. (2008) | USA | 62 hospitals | Collection and analysis of hospital and patient data. | Multivariate statistical analysis | – Implants are a major factor in the cost for knee replacement surgery (on average 42%), but complications and length of stay also impact costs  
– Variation in device costs, across hospitals, are difficult to justify  
– Substantial savings are possible if hospitals work together with surgeons since implant |
<table>
<thead>
<tr>
<th>Authors and Year of Study</th>
<th>Country of Study</th>
<th>Sample Size</th>
<th>Data Collection</th>
<th>Statistical Analysis</th>
<th>Main Conclusions</th>
</tr>
</thead>
</table>
| Premier Healthcare alliance database. (2011) | USA | 323 member hospitals 739 respondents | Analysis on member hospitals. Survey on health care leaders on physician preference purchasing and physician alignment. | Multivariate statistical analysis Qualitative Analysis | - Physician Preference Items increase hospital costs  
- Lack of transparency on device prices and wide variability in costs  
- Physicians work together with device companies |
| Robinson et al. (2012) | USA | 61 hospitals | Clinical, demographic and economic data were collected on 10 155 unilateral primary total knee replacement procedures and 5 013 unilateral primary total hip replacement procedures. | Multivariate statistical analysis | - Total hip replacement and total knee replacement implant costs vary by a factor of 7 and 5 respectively across patients |
| Alves et al. (2013) | Portugal | Continental Portugal | National Hospital Discharge Register database. Data on all discharges from 1st January 2000 to 31st December 2008 of individuals aged 50 years or over, with a diagnosis of hip fracture caused by a low or moderate trauma was analysed. | Generalized Additive Models | - Incidence of hip fractures is 70% higher in women than in men  
- Average age is higher in women (81 years) than in men (78 years) |
| Pabinger and Geissler | Portugal | Population from Economic and utilization rates data about hip arthroplasty | Absolute number of implantations and | - There is variation in the utilization of hip arthroplasty among OECD countries |

- devices vary by a factor of three ($3 408 - $10 830)
<table>
<thead>
<tr>
<th>Authors and Year of Study</th>
<th>Country of Study</th>
<th>Sample Size</th>
<th>Data Collection</th>
<th>Statistical Analysis</th>
<th>Main Conclusions</th>
</tr>
</thead>
</table>
| (2014)                    | OECD countries   |             | done in OECD countries between 1990 and 2011 were extracted. | compound annual growth rates were computed per 100,000 population and for patients aged 65 years old and over and for patients aged 64 years and younger. | - Increase in the utilization rate in most countries, especially in the younger patients  
- Exponential increase of revision rate is expected in the future. |

Source: Own Elaboration
As we may see, the majority of studies were conducted in the USA, with the exception of three that took place in Finland and in Portugal. Data collection was based on interviews to knowledgeable people from different hierarchical levels, within hospitals. Patient and hospital data were collected and analysed and surveys were answered by patients and health care leaders. Data was analysed through multivariate statistical analysis and qualitative analysis.

In terms of sample size, this varied between 1 and 323 hospitals and the studies were conducted between 2007 and 2013.

The studies conducted in the US address important points such as cost variations in and across hospitals, physician preference items management, cost saving opportunities, demand and surgery effectiveness in terms of health improvement and quality of life.

On the contrary, our literature review is very limited in terms of the breadth of studies conducted in Portugal. They analyse factors, other than implant costs, which we believe may influence total cost variations in hip and knee replacement surgeries, such as the average length of stay and complications, but nothing is presented about cost variations between and within Portuguese hospitals.

From the above table we can say that the first 3 studies are in depth and present high relevance for our study. The remaining are very relevant in terms of information on demand, age, gender and surgery effectiveness.

The study presented by the Premier Healthcare alliance database, in 2011, is very interesting, but is missing concrete values when it comes to the information on device prices and their variations.

3.3 Structure and Main Themes of the Study we are going to replicate

As we have mentioned before we are going to use the paper written by James C. Robinson and Emma L. Dolan (2008), “Device Costs, Total Costs, and Other Characteristics of Knee Replacement Surgery in California Hospitals”, with data from
2008, as a guide for our investigation. Unfortunately we will only have access to data from only two Portuguese hospitals.

In this issue brief, data on the annual volume of surgical procedures, device costs, total costs, length of stay, complications, reimbursements and patient characteristics in sixty-two hospitals, of which 17 only gave information on device costs, was collected. The relationship between hospitals and surgeons, knee implants as physician preference items and the efforts made by hospitals to manage device costs were also approached in this study.

The participating hospitals are diverse in terms of bed size, location (urban or rural), teaching status, profit or non-profit status and whether they are part of a larger hospital system.
4 Formulation and Explanation of Research Questions

The aim of our study is to answer the following questions:

1. Are there cost variations in total hip and knee replacement surgeries in Portuguese Hospitals?

We have seen in our literature review that cost variations in these types of surgeries, in the US, are significant. We would like to understand if this is the case for Portuguese hospitals.

2. Which factors influence cost variations in total hip and knee replacement surgeries in Portuguese Hospitals?

Understanding the reasons for cost variations is very important for better planning, management and allocation of economic resources.

3. Are implant costs the main factor affecting the total cost variation in total hip and knee replacement surgeries in Portuguese Hospitals?

Implant prices are in general considered the main cause for the variations that exist in hip and knee surgery costs and the latest trends, in the US, indicate that their prices are growing exponentially. We want to find out if implant prices are the factor with most impact on the final cost of a hip or knee surgery or if there are others that play a larger part in these differences. We also want to comprehend the weight each type of cost has in order to know where variations come from, if they make sense or are unnecessary and can be decreased or even eliminated.

4. Are hip and knee implants physician preferred items in Portuguese hospitals?

In many American studies, hip and knee implants are considered physician-preferred items. With this question, we want to see if this is the case in Portuguese hospitals, for Portuguese doctors. We also want to understand the power doctors have when it comes
to choosing implants for their patients and the number of options they have. Understanding this point will clarify how we should formulate strategies with the aim of decreasing costs and how to include doctors in this process.
5 Methodology of Our Study

We will now explain the methodology that was used for the research.

The research was conducted in Portugal, in the city of Porto. We collected data from 2012 and 2013 on two hospitals, one private and one public. Due to time, resource and budget limitations and also due to the lack of receptiveness of other hospitals to participate in the study only data from two hospitals will be used.

Patient records on those who went through total hip and/or knee replacement surgeries were collected and analysed. Costs are the main target of our study. We want to understand the cost variations within and across both hospitals in terms of procedure costs, device costs and hospitalization before discharge. In addition we also tried to understand the implant suppliers’ situation and bargaining power within the negotiation process.

In order to make both situations comparable (public hospital costs and private hospital costs) we organized costs into 3 distinct groups: implant costs, costs with the operating room and hospitalization costs. According to the way cost documentation is done in each hospital, we believe that this was the most accurate way to reach a cost for each patient who underwent a hip or knee surgery.

Information on patients’ gender, age, weight, length of stay, medication, and complications were requested, not only for analysis but also for control reasons, however costs with medication and complications weren’t given to us in a way we could analyse them separately, since they came included in surgery and hospitalization costs.

We want to comprehend PPIs’ impact on costs and how this issue is being managed and if it is a real problem in Portugal. For this, long interviews were conducted to orthopaedic surgeons and hospital managers, in order to understand both perspectives on PPIs and how each group perceives the other in conflict situations in terms of the
balance between cost effectiveness and quality received by patients. We tried to understand the hospital’s rules and how each actor impacts the decision process of selecting implants. We also attempted to understand who is involved in the negotiating process and how it is done.

We also conducted a survey, via email, to the main implant suppliers in Portugal because they are also very important actors, with a large impact on the implants which are chosen by hospitals and therefore impact strongly on one of the three main groups of costs which we will analyse: implant costs.

A summary of our methodology is presented in Figure 1: Methodology.
Figure 1: Methodology

- Literature Review
  - Definition of Variables to be Collected and Investigated
  - Data Gathering
    - Patient Records
      - Quantitative Analyses
        - Statistical Analyses (SPSS)
    - Questionnaire to Implant Suppliers
    - Long Interviews to Orthopaedic Surgeons
    - Long Interviews to Nurses
      - Industry Analyses
      - Qualitative Analyses
      - Critical Analyses and Results
5.1 Characterization of the private hospital and number of surgeries analysed

As we can see in Table 2: Population Universe – Private Hospital, the private hospital has 138 beds and between 2012 and 2013 performed, on average, 60 annual total hip surgeries and 68 annual total knee surgeries. The number of cases analysed will be of 63 hip surgeries and 80 knee surgeries in 2012 and 57 hip surgeries and 55 knee surgeries in 2013.

Table 2: Population Universe – Private Hospital

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Beds Available</td>
<td>138</td>
<td>138</td>
</tr>
<tr>
<td>No. Patients for Surgery</td>
<td>143</td>
<td>112</td>
</tr>
<tr>
<td>No. Hip Surgeries Analysed</td>
<td>63</td>
<td>57</td>
</tr>
<tr>
<td>No. Knee Surgeries Analysed</td>
<td>80</td>
<td>55</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

5.2 Characterization of the public hospital and number of surgeries analysed

The public hospital has 693 beds and between 2012 and 2013 performed, on average, 321 annual total hip surgeries and 296 annual total knee surgeries.

Table 3: Population Universe – Public Hospital

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Beds Available</td>
<td>693</td>
<td>693</td>
</tr>
<tr>
<td>No. Patients for Surgery</td>
<td>578</td>
<td>655</td>
</tr>
<tr>
<td>No. Hip Surgeries Analysed</td>
<td>94</td>
<td>121</td>
</tr>
<tr>
<td>No. Knee Surgeries Analysed</td>
<td>74</td>
<td>183</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

In 2012 and 2013 the number of patients who underwent a total hip or knee surgery or a revision surgery was superior in the Public Hospital. In 2012, 578 patients against 143 were operated and, in 2013, 655 patients were operated in the public hospital and 112 were operated in the private hospital. Unfortunately the sample sizes for the public hospital had to be reduced to 168 patients in 2012 and 304 in 2013, due to the absence
of some implant costs and errors in the system. The number of cases analysed will be of 94 hip surgeries and 74 knee surgeries in 2012 and 121 hip surgeries and 183 knee surgeries in 2013.

Unlike the private hospital, the public hospital is a teaching hospital associated with the Porto University. This has a very large impact on many aspects such as the way the hospital is organized, the speed at which things are done, the amount of resources used, labour costs and much more.

The population universe will be of 727 individuals, who underwent a total hip or knee surgery, between the 6\textsuperscript{th} of January of 2012 and the 30\textsuperscript{th} of December of 2013. All patients followed the hospital protocols.

**Table 4: Total number of Patients who did Surgeries 2012/13**

<table>
<thead>
<tr>
<th></th>
<th>Hip Surgery</th>
<th>Knee Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Hospital</td>
<td>120</td>
<td>135</td>
</tr>
<tr>
<td>Public Hospital</td>
<td>215</td>
<td>257</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

The statistical analysis was done using the SPSS statistics software version 21.0 from the International Business Machines Corporation.
6 Results

6.1 Quantitative Analysis

6.1.1 Descriptive Statistics

We will now present the most important and relevant points of our analysis to the data we collected, in order to prepare the reader for the main conclusions.

6.1.1.1 Types of Surgeries

The names of surgeries performed by each hospital seem to be different. In terms of variety it is difficult to reach a conclusion due to the fact that coding is done differently by each hospital. The public hospital uses codes from a list called homogeneous diagnostic groups, whilst the private hospital uses codes from a list called Código de Nomenclatura e Valor Relativo de Actos Médicos. For this reason, direct comparison is not possible since it’s a very specific clinical issue. Apart from this we were able to understand that in both cases there are more knee surgeries than hip surgeries.

6.1.1.2 Age

As we can see in Table 5: Hip Surgery, the average age of the patients at the time of the hip surgery was of 67 for the private hospital and of 69 for the public one. 60% in the private hospital and 67% in the public were aged over 65. At the time of the knee surgery (Table 6: Knee Surgery) the average age was of 68 for both hospitals and 64% of the patients, also in both hospitals were aged over 65.

Comparing these values to the ones above, presented by Alves et al. (2013), and by Kurtz et al. (2011), we see that the average age at which the Portuguese population undergoes hip surgeries might have changed. In 2008 average age was 80 years old and in 2012 and 2013 it was 68. It seems that more young people are being submitted to hip
surgeries. In terms of knee surgeries, also in Portugal in 2008, the percentage of patients with more than 65 years who did this surgery was of 73%, 9p.p. above the data we collected from both hospitals. As shown by W-Dahl et al. (2010), in a study conducted in Sweden, younger patients are being submitted to knee surgeries.

**Table 5: Hip Surgery**

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at the time of hip surgery (years)</td>
<td>67</td>
<td>69</td>
</tr>
<tr>
<td>Percentage of patients with more than 65 years</td>
<td>60%</td>
<td>67%</td>
</tr>
<tr>
<td>Percentage of women</td>
<td>54%</td>
<td>57%</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

**Table 6: Knee Surgery**

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average age at the time of knee surgery (years)</td>
<td>68</td>
<td>68</td>
</tr>
<tr>
<td>Percentage of patients with more than 65 years</td>
<td>64%</td>
<td>64%</td>
</tr>
<tr>
<td>Percentage of women</td>
<td>81%</td>
<td>79%</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

**6.1.1.3 Gender**

According to Table 5: Hip Surgery and Table 6: Knee Surgery, a predominance of females was observed for both types of surgeries and in both hospitals. For hip surgery the percentage of females was of 54% in the private hospital and of 57% in the public one. For knee surgery it was much higher, 81% and 79% for the private and public hospital respectively.

Once again, comparing these values to the ones presented by Alves et al. (2013), and Kurtz et al. (2011), they also show that these types of surgeries are more prevalent in women than in men and figures are very similar. In Portugal, in 2008, 60% of hip
fractures and 73% of knee surgeries were done in women.

6.1.1.4 Length of Stay

When looking at the average length of stay (Table 7: Length of Stay), we can observe that it is higher for the case of hip surgeries: 9 days for the private hospital and 11 for the public. The knee surgeries present an average length of stay of 6 days in the private hospital and of 9 in the public. For both types of surgeries, average length of stay in the public hospital is higher than in the private one, by 2 days in hip surgeries and 3 in knee surgeries. The number of days patients were hospitalized varies enormously. In the private hospital, the length of stay in hip surgeries varies between 1 to 42 days and in knee surgeries it varies from 1 to 21 days. In the public hospital, variations are between 3 to 74 days and 2 to 98 days respectively.

Table 7: Length of Stay

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average</strong></td>
<td>9 days</td>
<td>11 days</td>
</tr>
<tr>
<td><strong>Min-Max</strong></td>
<td>1 – 42 days</td>
<td>3 – 74 days</td>
</tr>
</tbody>
</table>

According to Portaria 234/2015, which gives us information on the diagnosis related groups, the average length of stay in the public hospital for hip replacement surgeries is on average of 10.87 days for severity level 1, 13.24 for severity level 2, 19.75 for severity level 3 and 47.48 days for severity level 4. In total knee replacement surgeries the averages for each severity level are of 8.16 days, 11.13 days, 14.12 days and 23.85 days respectively. When comparing these figures with those of the public hospital that we studied, we can see that the hospitals we analysed present low average values similar to those that correspond to severity level 1. In terms of hospitalization costs this is very beneficial.
6.1.1.5 Length of Stay Vs. Gender

We analysed data according to gender and then according to age, which we present below in Table 8: Total Hip Surgery and Table 9: Total Knee Surgery.

Table 8: Total Hip Surgery

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Length of Stay (Mean)</td>
<td>8.57</td>
<td>8.90</td>
</tr>
<tr>
<td>Age (Mean)</td>
<td>69.19</td>
<td>65.20</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

Table 9: Total Knee Surgery

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>Length of Stay (Mean)</td>
<td>6.49</td>
<td>6.32</td>
</tr>
<tr>
<td>Age (Mean)</td>
<td>68.36</td>
<td>67.44</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

In terms of gender some differences are worth mentioning. We can see that the length of stay is very similar in all cases of hip surgery except for women in the public hospital, 12.25 days. This means that, in the public hospital, on average women stay more 4 days in hospital than men and more 3.68 days than women stay in the private hospital.
In the case of a total knee surgery there is a small difference within hospitals, and a big difference between hospitals. The public hospital has higher mean values for the length of stay of around 3 days, for both women and men.
6.1.6 Age Vs. Gender

Total hip surgeries are performed in both hospitals to older women than men, in terms of mean values. In total knee surgeries, mean ages are 68 for women from both hospitals and 67 for men in the private hospital and 69 in the public one.

**Graph 5: Mean Age in Hip Surgery**

![Graph 5: Mean Age in Hip Surgery](source)

**Graph 6: Mean Age in Knee Surgery**

![Graph 6: Mean Age in Knee Surgery](source)
6.1.1.7 Implant Cost

With the data we gathered from each hospital, we analysed implant prices separately from other costs in order to understand their impact on hospital costs.

In terms of the number of prosthesis used in each hospital, the private hospital uses 21 different groups of hip implants and 11 different groups of knee implants, from 8 different suppliers and the public hospital uses 3 different groups of hip implants and only 1 group of knee implants, all from different suppliers.

<table>
<thead>
<tr>
<th>Table 10: Implants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Private Hospital</strong></td>
</tr>
<tr>
<td><strong>Hip</strong></td>
</tr>
<tr>
<td>No. Implants</td>
</tr>
<tr>
<td>No. Suppliers</td>
</tr>
<tr>
<td>Average Implant Cost</td>
</tr>
<tr>
<td>Min-Max Cost</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

The private hospital gave us access to information that allows us to know the price of each implant they used within the same types. We found out that implants from the same suppliers vary in terms of price. These variations can stand between 295 € and 7 219 €, but we do not have access to information on implant type details. Relating to Montgomery and Schneller (2007) they suggested that variations within the same types of implants were between 1 512 € and 6 804 € (exchange rate: 1$ = 0.756 €). Even though data in this study is from a different year it is still interesting to compare both situations.

Looking at Table 10: Implants, Graph 7: Average Hip Implant Costs and Graph 8: Average Knee Implant Costs we can conclude that the average implant costs in the private hospital are higher than in the public one. The difference between the minimum and maximum values are also greater in the private hospital. It is important to mention that the reason for such low values (212 € and 373 €) in private hospital
implants is that unfortunately the hospital includes the replacement of some prosthesis components in the same list as total hip and knee replacements, making no separation in the registering system.

**Graph 7: Average Hip Implant Costs**

Source: Own Elaboration, 2012/13

**Graph 8: Average Knee Implant Costs**

Source: Own Elaboration, 2012/13
According to Robinson et al. study, in 2012 in Californian hospitals, variation in implant devices for total knee surgery was between 1 359 € and 9 142 € and for total hip surgery was between 1 808 € and 9 564 € (exchange rate: 1$ = 0.756 €).

Below, in Graph 9: Hip Implant Costs, we can see all the different implant costs used in our sample in both hospitals. As we can see, variation is much larger in the private hospital than in the public one, since this last one only uses 3 different types of implants against 21 used in the private hospital, as has been mentioned above.

**Graph 9: Hip Implant Costs**

Source: Own Elaboration, 2012/13

In Graph 10: Knee Implant Cost, we can see how the public hospital only uses 1 type of knee implant for the exact same price and how the private hospital presents 11 different implants with different prices.
6.1.1.8 Operating Room Cost

In the public hospital, the cost with the operating room was calculated by multiplying the time the patient was in surgery, in hours, by the cost the hospital has per hour of usage of the operating room.

\[
\text{Operating Room Cost}_{\text{public hospital}} = \text{Hours in Surgery} \times \text{Cost per hour}_{\text{public hospital}}
\]

The cost per hour was calculated by dividing the total cost that the hospital has with the usage of the operating room, for orthopaedic surgeries, throughout one year by the total number of hours that it was used in that same year.

\[
\text{Cost per hour}_{\text{public hospital}} = \frac{\text{Total Cost}_{\text{year}}}{\text{Total Hours}_{\text{year}}}
\]

The total cost of using the operating room during one year includes: pharmaceutical products, consumed materials and resources (clinical, administrative, cleaning, maintenance), services, human resources and equipment.

In the private hospital, the cost with the operating room was calculated by the same way as in the public hospital.

\[
\text{Operating Room Cost}_{\text{private hospital}} = \text{Hours in Surgery} \times \text{Cost per hour}_{\text{private hospital}}
\]
The difference lies in the way the cost per hour was calculated. In the private hospital they divide the total cost that the hospital has with the operating room throughout one year, for all types of surgeries and not only for orthopaedic surgeries, by the total number of hours that it was open in that same year. The operating room is open between 8am and 11pm from Monday through Friday. Orthopaedic surgeries represent the major bulk of surgeries done in the operating room (25%).

\[
\text{Cost per hour}_{\text{private hospital}} = \frac{\text{Total Cost}_{\text{year}}}{\text{Total hours}_{\text{year}} \times \text{between 8am and 11pm}}
\]

The total cost of using the operating room for one year includes the same costs as the ones in the public hospital.

As we can conclude from Table 11: Operating Room Cost, the average costs with the operating room are higher in the private hospital by 259 € for hip surgeries and by 599 € in total knee surgeries.

<table>
<thead>
<tr>
<th>Table 11: Operating Room Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private Hospital</td>
</tr>
<tr>
<td>Hip</td>
</tr>
<tr>
<td>Average</td>
</tr>
<tr>
<td>Min-Max</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

**6.1.1.9 Hospitalization Costs**

In the public hospital, the hospitalization cost was determined by multiplying the number of days a patient is hospitalized by the average daily cost it has for the hospital, which includes the following: pharmaceutical products, consumed materials (except implant) and resources (clinical, administrative, dietary, cleaning, maintenance), services, human resources, room furniture and equipment.

\[
\text{Hospitalization Cost}_{\text{public hospital}} = \text{Number Days} \times \text{Average Daily Cost}
\]

In the private hospital, it was determined in a more specific way. The pharmaceutical products and the clinical consumed materials are specific for each patient, then to these costs the average daily cost (without pharmaceutical products and the clinical consumed materials) multiplied by the number of days a patient is hospitalized is added on. The
average daily cost includes the following: consumed materials and resources (administrative, dietary, cleaning, maintenance), services, human resources, room furniture and equipment. We must mention that in the private hospital there are more room options for patients and according to their characteristics some are more expensive than others.

\[
\text{Hospitalization Cost}_{\text{private hospital}} = \text{Pharmaceutical Products} + \text{Clinical consumed Materials} + (\text{Number Days} \times \text{Average Daily Cost})
\]

As we can determine from Table 12: Hospitalization Cost, this cost is higher for total hip surgery than for total knee surgery in both hospitals and such as the rest of the costs, analysed above, it is more expensive for the private hospital than for the public one.

<table>
<thead>
<tr>
<th>Table 12: Hospitalization Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Private Hospital</strong></td>
</tr>
<tr>
<td>Hip</td>
</tr>
<tr>
<td>Knee</td>
</tr>
<tr>
<td><strong>Average</strong></td>
</tr>
<tr>
<td>2 675 €</td>
</tr>
<tr>
<td>1 952 €</td>
</tr>
<tr>
<td><strong>Min-Max</strong></td>
</tr>
<tr>
<td>88 € - 14 516 €</td>
</tr>
<tr>
<td>182 € - 7 067 €</td>
</tr>
<tr>
<td><strong>Public Hospital</strong></td>
</tr>
<tr>
<td>Hip</td>
</tr>
<tr>
<td>Knee</td>
</tr>
<tr>
<td><strong>Average</strong></td>
</tr>
<tr>
<td>1 925 €</td>
</tr>
<tr>
<td>1 615 €</td>
</tr>
<tr>
<td><strong>Min-Max</strong></td>
</tr>
<tr>
<td>546 € - 13 468 €</td>
</tr>
<tr>
<td>366 € - 17 836 €</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

As explained before, in both hospitals, the cost with hospitalization is calculated using the number of days that a patient is hospitalized. For this reason the variance between values can be very large from one situation to another due to the large variances in terms of the number of days patients are hospitalized, as above was explained.

### 6.1.1.10 Total Cost

The difference in the average total cost is of 1 804 € in total hip surgery and of 1 123 € in total knee surgery between the hospitals, being the private one presenting the highest values. In both hospitals, total hip surgery has a higher total cost than knee surgery. In addition, variations for total hip surgery and knee surgery are big. Comparing these values to the 6 800 € presented in the OECD (2014) report for the average total cost of hip and knee surgeries in Portugal we can say that both hospitals are below this average value.
Table 13: Total Cost

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hip</td>
<td>Knee</td>
</tr>
<tr>
<td>Average</td>
<td>6 282 €</td>
<td>5 226 €</td>
</tr>
<tr>
<td>Min-Max</td>
<td>3 051 € - 19 898 €</td>
<td>3 275 € - 11 207 €</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

According to Diário da República, Portaria n.º 234/2015 (2015), across the different severity levels, the total price attributed to hip surgery varies between 3 737 € and 17 680 € and in knee surgery varies between 3 649 € and 13 949 € in public hospitals. In the case of the public hospital that we analysed and for both types of surgeries, we can see that mean values are very close to the minimum of the defined interval and in all cases, with the exception of one knee surgery (24 018 €), all values stand within the intervals.

Finally, measuring the weight of each part of the total cost (implant, operating room, hospitalization cost) we see that, for the hip surgery, in both hospitals, the implant cost is not the one with most weight. In the private hospital the implant cost has a weight of 31%, operating room cost has a weight of 30% and hospitalization cost has a weight of 39%. In the public hospital the weights are 26%, 34% and 39% respectively. In both cases hospitalization cost is the one with the largest weight on total cost and presents the same percentage.
Graph 11: Costs - Hip Surgery in Private Hospital

Source: Own Elaboration, 2012/13

Graph 12: Costs - Hip Surgery in Public Hospital

Source: Own Elaboration, 2012/13
In knee surgery, for the private hospital, operating room cost is the one with the largest weight – 37%. Then with 35% we have the hospitalization cost and the implant cost is the smallest one with a weight of 28%. In the public hospital, hospitalization has the largest weight, 37%, then the implant cost, 33%, and lastly the operating room cost with a weight of 30%. According to Robinson and Dolan (2008) there is high variation in total costs for knee surgeries within and across Californian hospitals and these can be lowered internally (errors, finding cost saving opportunities) and externally (suppliers’ power). In both public and private hospitals we analysed this may also be applied internally (lowering of operating room and hospitalization costs through the reduction of surgery errors and better human resource and material management) and externally (reduction of implant costs through negotiation with suppliers), since these are the costs that build up total costs with these types of surgeries.

**Graph 13: Costs - Knee Surgery in Private Hospital**

![Graph showing costs breakdown for knee surgery in a private hospital](source: Own Elaboration, 2012/13)
With this, when comparing the weight of the implant, operating and hospitalization cost in the total cost for both surgeries and in both hospitals we see that the implant cost is not the one with the largest weight in the average total cost.

6.1.1.11 Average Daily Cost

The average daily costs for each hospital were calculated by dividing the total costs the hospitals have with hospitalization by the total number of days patients were hospitalized.

\[
\text{Average Daily Cost} = \frac{\text{Total Hospitalization Costs}}{\text{Total number of Days}}
\]

As we can see in Graph 15: Average Daily Cost in Hip Surgery and Graph 16: Average Daily Cost in Knee Surgery the average daily cost in the private hospital is higher than in the public hospital, for both types of surgeries and in both years.
Graph 15: Average Daily Cost in Hip Surgery

![Graph 15: Average Daily Cost in Hip Surgery](image)

Source: Own Elaboration, 2012/13

Graph 16: Average Daily Cost in Knee Surgery

![Graph 16: Average Daily Cost in Knee Surgery](image)

Source: Own Elaboration, 2012/13
6.1.1.12 Gender vs. Costs

Table 14: Total Hip Surgery

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td><strong>Implant Cost (Mean)</strong></td>
<td>2 011.84 €</td>
<td>1 722.05 €</td>
</tr>
<tr>
<td><strong>Operating Room Cost (Mean)</strong></td>
<td>1 707.90 €</td>
<td>1 751.76 €</td>
</tr>
<tr>
<td><strong>Hospitalization Cost (Mean)</strong></td>
<td>2 768.97 €</td>
<td>2 565.85 €</td>
</tr>
<tr>
<td><strong>Total Cost (Mean)</strong></td>
<td>6 488.71 €</td>
<td>6 039.66 €</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

Table 15: Total Knee Surgery

<table>
<thead>
<tr>
<th></th>
<th>Private Hospital</th>
<th>Public Hospital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td><strong>Implant Cost (Mean)</strong></td>
<td>1 459.60 €</td>
<td>1 389.22 €</td>
</tr>
<tr>
<td><strong>Operating Room Cost (Mean)</strong></td>
<td>1 835.04 €</td>
<td>1 795.52 €</td>
</tr>
<tr>
<td><strong>Hospitalization Cost (Mean)</strong></td>
<td>1 957.49 €</td>
<td>1 925.88 €</td>
</tr>
<tr>
<td><strong>Total Cost (Mean)</strong></td>
<td>5 252.13 €</td>
<td>5 110.61 €</td>
</tr>
</tbody>
</table>

Source: Own Elaboration, 2012/13

We have already mentioned above how in general, average costs in the private hospital are above those in the public hospital. When analysing cost variations within each hospital, for total hip surgeries, the most significant differences between genders are in the implant costs, in the private hospital, and in hospitalization and total costs, in the public hospital. Mean values for these three cases are higher for women than men. Implant costs are higher by 300 €, hospitalization costs are higher by 700 € and total costs are higher by around 2 500 €, respectively. We can have a closer look at these variations through the following graphs:
Graph 17: Implant Cost vs. Gender (Hip Surgery in Private Hospital)

Graph 18: Hospitalization Cost vs. Gender (Hip Surgery in Public Hospital)

Source: Own Elaboration, 2012/13
In terms of total knee surgery the greater differences lie in the total costs between both hospitals. The differences between mean values are around 1 000 €.

Source: Own Elaboration, 2012/13
6.1.2 Inferential Statistics

Throughout our literature review we have seen that there are great variations in implant costs both across and within American hospitals. We have also confirmed that variations within the private hospital occur in implant costs. In the public hospital things seem to be more standardized and the same types of implants present the same price. We will now understand what happens to implant costs across both hospitals and in terms of gender.

In this section we present the main conclusions of inferential statistics. For a more detailed analysis see point 9.4 in the appendix section.

We started with a Test for equality of means to understand if we can extrapolate results to the population (Table 18 and Table 19). Then we present 4 estimating models (Table 20) in order to understand how the variance in total cost and implant cost, for both surgeries, are explained by some of the variables.
Table 16: Hip Implant Cost

<table>
<thead>
<tr>
<th>Sig (Pvalue)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of hospital (Public or Private)</td>
<td>0.000 The means for hip implant costs ($\mu_{Private}$ and $\mu_{Public}$) are significantly different and therefore, based on the sample, we can affirm that $\mu_{Private} &gt; \mu_{Public}$ with 95% of confidence. Variances are also different.</td>
</tr>
<tr>
<td>Gender</td>
<td>0.087 The means for hip implant costs ($\mu_{Female}$ and $\mu_{Male}$) are equal with 95% of confidence. Variances are also equal.</td>
</tr>
</tbody>
</table>

Table 17: Knee Implant Cost

<table>
<thead>
<tr>
<th>Sig (Pvalue)</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of hospital (Public or Private)</td>
<td>0.000 The means for knee implant costs ($\mu_{Private}$ and $\mu_{Public}$) are significantly different and therefore, based on the sample, we can affirm that $\mu_{Private} &gt; \mu_{Public}$ with 95% of confidence. Variances are also different.</td>
</tr>
<tr>
<td>Gender</td>
<td>0.426 The means for knee implant costs ($\mu_{Female}$ and $\mu_{Male}$) are equal with 95% of confidence. Variances are also equal.</td>
</tr>
</tbody>
</table>

Table 18: Linear Regression Models - Variables 1

<table>
<thead>
<tr>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip Surgeries</td>
<td>Knee Surgeries</td>
<td>Hip Surgeries</td>
<td>Knee Surgeries</td>
</tr>
<tr>
<td>Total cost</td>
<td>Implant cost</td>
<td>Total cost</td>
<td>Implant cost</td>
</tr>
<tr>
<td>$\beta_1 = $Hospital</td>
<td>$\beta_1 = $Hospital</td>
<td>$\beta_1 = $Hospital</td>
<td>$\beta_1 = $Hospital</td>
</tr>
<tr>
<td>$\beta_2 = $Gender</td>
<td>$\beta_2 = $Gender</td>
<td>$\beta_2 = $Gender</td>
<td>$\beta_2 = $Gender</td>
</tr>
<tr>
<td>$\beta_3 = $Length of Stay</td>
<td>$\beta_3 = $Age</td>
<td>$\beta_3 = $Length of Stay</td>
<td>$\beta_3 = $Age</td>
</tr>
<tr>
<td>$\beta_4 = $Age</td>
<td>$\beta_4 = $Age</td>
<td>$\beta_4 = $Age</td>
<td>$\beta_4 = $Age</td>
</tr>
<tr>
<td>$\beta_5 = $Implant Cost</td>
<td>$\beta_5 = $Implant Cost</td>
<td>$\beta_5 = $Implant Cost</td>
<td>$\beta_5 = $Implant Cost</td>
</tr>
</tbody>
</table>

Table 19: Linear Regression Models - Variables 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 – Public</th>
<th>0 – Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1 – Female</td>
<td>0 – Male</td>
</tr>
</tbody>
</table>

52
Table 20: Estimated Models

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hip Surgeries</td>
<td>Knee Surgeries</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total cost</td>
<td>Implant cost</td>
<td>Total cost</td>
<td>Implant cost</td>
</tr>
<tr>
<td>Constant</td>
<td>1326.7</td>
<td>2161.9</td>
<td>1726.6</td>
<td>1431.6</td>
</tr>
<tr>
<td>Hospital</td>
<td>-1351.0**</td>
<td>-788.9**</td>
<td>-1448.4**</td>
<td>-186.8**</td>
</tr>
<tr>
<td>Gender</td>
<td>9.7</td>
<td>46.5</td>
<td>-43.8</td>
<td>49.2**</td>
</tr>
<tr>
<td>Length of stay</td>
<td>212.4**</td>
<td></td>
<td>211.4**</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>15.6**</td>
<td>-4.6</td>
<td>11.6**</td>
<td>-0.1</td>
</tr>
<tr>
<td>Implant cost</td>
<td>1.1**</td>
<td></td>
<td>1**</td>
<td></td>
</tr>
<tr>
<td>Coefficient of Determination: $R^2$</td>
<td>0.844</td>
<td>0.274</td>
<td>0.858</td>
<td>0.053</td>
</tr>
<tr>
<td>% of dependent value variance which is explained by the model</td>
<td>84.4%</td>
<td>27.4%</td>
<td>85.8%</td>
<td>5.3%</td>
</tr>
<tr>
<td>Is the model globally significant?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

** Variable is statistically significant for a 5% significance level.

6.1.2.1 General Conclusions

As we can see from Table 20: Estimated Models, all models are globally significant and models 1 and 3 explain 84.4% and 85.8% of total cost variance, in hip and knee surgeries respectively. This is not the case of models 2 and 4, which only explain 27.4% and 5.3% of implant cost variance in hip and knee surgeries.

In models 1 and 3 all variables except for gender are statistically significant for a 5% significance level. In models 2 and 4 only the variable hospital is statistically significant for a 5% significance level.
6.2 Qualitative Analysis

6.2.1 Questionnaires to Implant Suppliers

To better understand the orthopaedic implant market in Portugal, we decided to build a questionnaire for hip and knee implant suppliers in Portugal. Our questionnaires were sent and answered via e-mail.

This questionnaire was sent to 7 different suppliers – MBA, Biomet, Artur Salgado, Zimmer, Stryker, Smith Nephew, Depuy – but unfortunately only 3 companies answered. For confidentiality reasons, these cannot be named.

As we will now analyse, in terms of answers, some were very similar, but others were contradictory.

We were told that during the last few years and until today this market has suffered a lot. Hospitals have debt since 2011 and therefore they take a long time to pay suppliers. The profit margin for these companies is minimum and hospitals continue to make pressure in order to decrease implant prices as much as possible. According to the suppliers, they need to be in a good financial situation in order to bear with all this and survive whilst waiting for all late payments.

The purchasing of knee and hip implants is a very important moment for a hospital, since it has a great impact in terms of costs. In fact, and from our cost analysis, implants are a large cost for hospitals, but aren’t the largest one. From the analysis of graphs Graph 11: Costs - Hip Surgery in Private Hospital, Graph 12: Costs - Hip Surgery in Public Hospital, Graph 13: Costs - Knee Surgery in Private Hospital and Graph 14: Costs - Knee Surgery in Public Hospital, in the private hospital the weight of implant cost comes in last after operating room cost and hospitalization cost and in the public hospital it comes in second after hospitalization cost.
We also learned that Hospitals have a committee, composed by orthopaedist doctors, which are responsible for choosing the implants. They influence this purchasing process, but some have a stronger word than others, depending on the institution they work in. Doctors try the implants and keep using them if they like the technique the implant requires and the material they are made of. In general, in private hospitals doctors have a larger weight in the choice of the implants, than in public ones. In public hospitals suppliers present material where each one offers their best proposal and then the hospital choses the winner. In private ones the material doctors request for and use in large volumes is then negotiated in terms of price between the hospital and suppliers.

Specifications on implants influence the number of suppliers participating in the bidding process. On one hand there are hospitals that have such detailed technical specifications, when requesting for implants, that give little to no space for a large number of suppliers to participate. Sometimes when doctors want a specific brand they define specifications in a way that only the brand they want will be able to offer them the implants. On the other hand, there are situations in which hospitals do not demand for any specifications and therefore give an opportunity for all suppliers to participate in the bidding process. According to the interviews, done to the implant suppliers, at the moment these situations are 50/50, but more and more technical specifications are tighter. Also, doctors prefer to keep on using what they are used to and aren't much open to change, a natural tendency of all human beings, which is named as the status quo fallacy.

When deciding between similar implants, the factors that have the largest weight are in first place the price with a weight of 60% and in second the technical merit with a weight of 40%. Price is valued a lot; it is considered a fundamental factor in terms of decision-making. The technical merit varies a lot from hospital to hospital. A supplier can offer a lower price, but still lose the client against a more expensive supplier in the case doctors value more the technical merit against price benefits. Still we cannot forget the importance of patients’ characteristics in the choice of the implant, but the problem, once again, is that even though implants are always being innovated doctors are very reluctant when it comes to trying something new.
In the Portuguese hip and knee implant market standard products have much greater demand than custom-made ones.

The companies that answered our questionnaire stated that implants do not vary in terms of quality even though their prices may be different.

In terms of effectiveness there are implants, made out of certain materials, which are better than others and bring better results. These are also more expensive. Effectiveness also depends on the doctor's skill when performing the surgery and on the patient’s pathology. This information is contradictory to what was said above in terms of quality variances.

Another factor taken into consideration in terms of implant prices was if the hospital is public or private. On one hand, we were informed that implant prices vary in terms of the type of material which they are made of, production and post-sale assistance requirements and that it has nothing to do with the type of institution it is being sold to (public or private), but on the other hand we were also told that the type of organization to which implants were sold affected their final price.

When comparing hospital choices we found out that suppliers have different points of view. Some believe that there are no differences. Others believe that differences come, in most cases, from doctors’ criteria and not from the type of hospital. And a third opinion is that hospitals choose differently. Private hospitals ask for a tender to a large or small number of suppliers and then doctors analyse what patients need. Public hospitals have a ‘one implant serves all’ philosophy and finally, the Portuguese Institute of Oncology (IPO) accepts custom-made implants. This is in line to what we saw in the two hospitals we studied.

6.2.2 Questionnaires to Orthopaedic Surgeons

We interviewed the surgeons that perform the higher number of hip and/or knee surgeries in each hospital. In the public hospital we interviewed one surgeon for each
kind of surgery and in the private hospital we only interviewed one surgeon that performs both types of surgery.

All surgeons explained that age is the main cause for the need of hip and knee joint replacement surgeries. This is in part in line with what Dugdale and Zieve (2013) and Carr et al. (2012) present in their studies. The first study also includes weight as one of the main risk factors for hip and knee surgeries and the second study presents age and weight as the main risk factors and bone density, bone morphology, meniscal derangement, gender, sex hormones, and trauma as other risk factors. It is very interesting to relate this information to the fact that these types of surgeries are more predominant in women than in men in Portugal, not only in Alves et al. (2013) but also in both hospitals we analysed, and how women suffer more from obesity problems than men, also in Portugal, as the OECD (2014) report shows.

In the private hospital, the type of surgery (primary or revision) and the type of prosthesis (cemented or non-cemented) are the factors that increase surgery duration in both a total hip and knee surgery. In the case of a primary surgery it can take between 1 and 1.5 hours against 3 to 5 hours in the case of a revision surgery. In the case of a cemented prosthesis, these ones take up 20 minutes just to become solid, which is not the case for a non-cemented one. In the public hospital, both surgeons, point out that the anaesthesia is the main factor. A general anaesthesia takes less time than a spinal anaesthesia, but gives a worst post-operative phase. In the case of a knee surgery, the level of difficulty of the knee and the anaesthetists’ experience also increase highly on the time the surgery takes.

In the private hospital’s surgeon opinion, the length of stay after a hip or knee surgery is influenced by patient’s comorbidities (cardiac, pulmonary, renal insufficiency), patient’s intraoperative complications and weight (the lighter the faster the recovery). In the public hospital’s surgeon opinion, complications are the main cause for both types of surgeries. Additionally, patient’s general health state before operation, age, comorbidities and home support were also pointed out for the case of knee surgery.
In terms of costs, all surgeons in both hospitals pointed out implants as the main factor that aggravates costs. Then, in the private hospital, for both surgeries, human resources and their skill are another important factor (the lower the skill level the higher the costs due to the increase in surgery duration). In the public hospital, for the case of a knee surgery, the extending of anaesthesia, surgery time and length of stay were also mentioned.

Suggestions on how to improve efficiency in hip and knee surgeries varied. In the private hospital the orthopaedic surgeon proposed, for both surgeries, the use of highly skilled and experienced surgeons and very good surgical programming, through the use of software that permits surgeons to know, in advance, which prosthesis to use, its size, position and all the measurements. In the public hospital, reducing complications, such as infections that affect costs a lot was suggested for the case of hip surgeries and reducing the time until patient reaches the operation room and enters and anaesthesia time were suggested for the case of knee surgeries.

Choosing prosthesis for each patient varies. In the case of hip surgeries, the private hospital has protocols, which they follow, and these depend on patient’s age: the more expensive prosthesis are used for younger patients and the materials are harder than the cheaper prosthesis that are used on older patients. In the surgeon’s opinion, even though weight isn’t taken into consideration for the choice of the prosthesis, it should be. He normally asks his heavier patients to lose weight before the operation.

In the public hospital the choice has also to do with age and bone health: non-cemented for younger patients and with better bone and cemented for older patients and with osteoporosis. This surgeon has a different opinion form the one from the private hospital, since he feels that weight and also height do not influence the type of prosthesis chosen, but the technique used. In knee surgeries the private hospital also follows protocols that depend on age. In the public hospital surgeons have no options; they only have one type of prosthesis, which they must use. They can only ask for a different one in very specific cases. This surgeon stated that choosing the prosthesis depends on the type of arthritis the knee has and not on weight and age. He explained
that the ideal situation is to put knee prosthesis as late as possible, after the age of 65, but each case is a different case. If a patient is young, but has the knee in such a way that he doesn’t have quality of life the surgery is done. This is in line with Carr et al. (2012) and Keeney et al. (2010), which state that knee surgery relieves pain, increases knee function and therefore quality of life and durability is expected with knee replacement surgeries and so it is increasingly done to younger patients. The surgeon we interviewed from the public hospital also alleged that if the case is of someone who cannot leave bed, then independently of the age it doesn’t make sense to go through a knee surgery.

Going deeper into the age as a factor that affects prosthesis choice for hip surgery, we found out that in the private hospital the choice of an implant varies according to 3 age gaps: less than 65, 65 years and more, less or equal to 80, more than 80. In the Public hospital the choice of an implant varies also according to 3 age gaps: < 65 (non-cemented), > 65 - < 70 (depends on bone quality), > 70 (cemented).

Choosing the prosthesis involves a whole process developed by the hospitals. In the private hospital we are speaking about a basic economical process, composed of a committee with doctors and members of management, where the hospital has 5 to 6 big brands and not one has everything the hospital needs. The criterion is price within high quality and logistics support (capacity and speed to replace stocks, technical teaching). The frequency at which this process takes place is once a year, but will become once every two years because prosthesis do not change much, so there is no need to go through this every year. In the public hospital, from the surgeons we interviewed, only the hip surgeon is involved in this selection process, and he explained that the process takes place every 3 to 5 years, but in the interviewee’s opinion it should be every year or every two years. Doctors elaborate a plan of the types of prosthesis they want and their characteristics, then according to their price, a decision is taken by the provision department.
From what we have seen in the literature review, implants, as physician preference items, originate conflict between the actors, doctors and management team, involved in their selection process, since they impact highly on costs. Knowing this we wanted to investigate if this was the case in the two Portuguese hospitals we studied.

In both hospitals there seems to be no conflict between doctors and between doctors and administration. This defined price reduces largely the space for conflict between the involved actors. The reason for this in the private hospital is the fact that committee members are aligned with each other and have the same goals and really believe in the system their hospital has. With this we can conclude that implants are not seen as physician preference items in both hospitals, of our study, by the doctors and administrators we interviewed.

From the suggestions done by Tyson (2010) for better physician preference item’s management, both the private and public hospital we studied follow the majority of them. In first place, protocols and randomized studies are used for hip and knee implant choice. In second place, negotiation for best prices take place in both hospitals, through a number of different vendors, preventing the lock-in-dilemma, and through quantity discounts. In third place, a team that includes doctors, in order to guarantee cost-cutting opportunities, chooses implants. The only suggestion presented by Tyson (2010) that wasn’t pointed out throughout the interviews was the use of lean and six-sigma methodologies in both hospitals.

When choosing prosthesis, different factors are taken into consideration, but in both hospitals, and for both surgeries, price is the main one; just as explained above in the answers given by implant suppliers. In the private hospital, quality, replacement capacity, technical support and staff training (learning curve is slow due to the millions of instruments used in each prosthesis) are also important for hip and knee implants. In the public hospital the implant characteristics that doctors want are also very important for decision making in the case of the implants for hip surgeries. For knee implants, supplier proposals, guarantees and conditions also have some weight. These are in line
with factors such as the functional level of an implant and physician’s familiarity with
the device, but aren’t in line with the idea that surgeon preferences are based on device
brand and brand loyalty, suggested by Robinson and Dolan (2008) and Wilson et al.
(2008).

In terms of the number of prosthesis each hospital may choose, we have seen that the
public one is much more limited, just having 3 types for hip surgery and only 1 for knee
surgery against 21 hip implants and 11 knee implants in the private hospital.

Furthermore, both hospitals feel that the number of prosthesis they choose is enough.
All surgeons explained that it would make no sense being able to choose more because
that would imply more costs. More implants would mean more instruments, higher
storage, replacement and learning costs. As Robinson and Dolan (2008) explain
switching suppliers and therefore the implants physicians use imply switching costs:
surgeons will need time to adapt and learn how to use the new implant and its related
instruments.

From the prosthesis chosen by the hospitals there are some differences, even if very
small. Contrary to what implant supplier companies said, in the private hospital these
differences are in terms of quality (randomized studies which show quality and results
and on which choices are based), price and supplier capacity to answer hospital needs.
In the public hospital there are very small quality differences (manufacturers improve
what already exists without violating patents).

In *Hospitals’ Strategies for Orchestrating Selection of Physician Preference Items*,
Montgomery and Schneller (2007) suggest the creation of standards for product choice
of PPIs, something that could also be very useful in our hospitals in case the protocols
we use aren’t sufficient.
We also learned, in the same paper, that more than fifty different prostheses were being used in the United Kingdom, and of which only seven of these implants showed good results and only four of these seven were being used in the National Health Service. This does not seem to be the case in the Public hospital that we studied. As we have seen above, they have and follow protocols. The surgeon performing knee surgeries, in the public hospital, explained that what matters is that the surgery goes well. He added that some implants may have more options in terms of sizes, instruments and may make it easier.

In the private hospital, the chosen prosthesis are among the ones with highest quality and best results, according to randomized studies on these matters, but still there are many differences in the results from different types of implants. The reason for this is that prosthesis are always evolving and results are only seen 5 or 10 years after the surgery.

In terms of prosthesis prices (approximate values) the answers were not identical. For hip surgery, the orthopaedic surgeon from the private hospital identified the following values for each type of implant: cemented – 500 €, non-cemented - 1 200 €, with ceramic component - 1 500 €. In the public hospital an average price of 1 500 € was pointed out. For knee surgery the surgeon from the private hospital explained it ranged between 800 € and 1 000 € whilst the surgeon from the public hospital, who isn’t part of the team that choses the prosthesis for the hospital, believed it would be around 2 000 €.

Comparing the values pointed out in the interviews by the surgeons with the average implant costs of our data from Table 10: Implants we can say that the private hospital presents higher values for both types of surgeries, by around 400 € than those indicated by the surgeons and the public hospital presents average prices, for both surgeries, at least 400 € below than those indicated by the surgeons in the interviews.

Confronting these values with the ones presented by Montegomery and Schneller (2007) in the literature review, we can see that the prices for implants in the United
States are much higher (1 512 € - 6 804 €) than those indicated by the surgeons (500 € – 2 000 €) and the data collected from the hospitals (1 084 € - 1 879 €). The average cost for a hip surgery in the private hospital (6 282 €) and in the public hospital (4 478 €) remains between the costs of US hospitals included in the study (1 808 € - 9 564 €). The average cost for a knee surgery in the private hospital (5 226 €) and in the public hospital (4 103 €) also remains between the range of costs of US hospitals (1 359 € - 9 142 €) in the study presented by Robinson et al. (2012).

We tried to understand the perspective each surgeon, from each hospital, has on the differences and similarities between the way prosthesis are chosen in a public and a private hospital. The surgeon from the private hospital explained to us that in their hospital, what matters is scientific evidence: guidelines/protocol and that in other hospitals, public or private, guidelines are followed more or less than they do. In the public hospitals the surgeon who performs hip surgeries stated that the processes are very similar and that in a public hospital, due to the larger number of surgeries, they can manage to benefit from quantity discounts. On the contrary the surgeon who performs knee surgeries elucidated us to the fact that in public hospitals it has all to do with prosthesis costs and while they just have 1 implant to use, private hospitals have normally 3.

As we have seen before, revision surgeries are expected to increase in the future. This type of surgery is needed when the implant is mechanically put in a wrong way, when the patient’s body reacts badly to the material causing allergies and infection, when it is the wrong size or when it is worn out due to the patient’s high level of activity or excess weight. Also, surgeons recommend that revision surgeries be done as late as possible. It is a very clinical matter, which is subjective and very difficult to detect when there is a need for it.

In terms of cost, a revision surgery is much more expensive than a primary surgery. The surgeon from the private hospital explained that it is very difficult to give a value for the cost because every revision surgery has its cost. It is also a complicated surgery because it needs bone insertion and in Portugal it is very difficult to get, they have to be sent from Coimbra. The hip surgeon from the public hospital referred that the cost of a
Revision hip surgery is twice the one of a primary hip surgery. The knee surgeon from the same hospital explained that it also depends on what needs to be done. If wearing is very big some small blocs must be introduced and each of these costs around 500 € and only a prosthesis with no blocs costs around 5 000 €.

There is no consensual opinion on the lasting of total hip and knee surgeries. On one hand, in the private hospital, the opinion is that such surgeries last 20 or more years and that the number of years has been increasing. The knee surgeon form the public hospital shares the same opinion, but adds that in case of complications (dislocation or infection) they last much less than 20 years. He also explains that it depends on the age of the patient. A patient who had the surgery at the age of 50 and is active will wear out the prosthesis much more than in a 70 year old who isn’t active and who will probably never have to change it again before dying. He refers it is difficult to compare with past trends, since now many more surgeries are done (300/year - 3 times more) and there have been more revisions and doing more knee surgeries leads to a higher number of complications too (not in percentage terms). He finalizes by stating that there have been less technical errors, materials have been improving and therefore implants last longer. On the other hand the surgeon from the private hospital shares a different opinion and says that these surgeries last always above 10 years, but unfortunately the number of years hasn’t been increasing, which is a paradox. He explains that prosthesis which in 97% of the cases still function well after 20 years were designed in 1960. Contrary to what happens with pharmaceuticals, implants do not have to pass through many tests during many years before they are sold and therefore sometimes there are situations that don’t go well. This is not the case for hip implants and the FDA approves very easily when the material is biocompatible.

When patients are discharged they in general go home using crutches. Patients have an average length of stay between 5 and 7 days, but the range is between 5 and 15 days. The number of days for the average length of stay are a little higher than the interval presented by Robinson and Dolan (2008) of 2.4 to 6 days and lower than the average values we reached from the two hospitals we analysed: 9 days for hip surgeries and 6
days for knee surgeries in the private hospital and 11 days for hip surgeries and 9 days for knee surgeries in the public hospital.

If a patient lives far away and he will have to come back to the hospital a couple of days after being discharged the hospital lets him stay. The doctor explained that patients must have their houses prepared for when they go back home, so the hospital gives them a guide that explains all the safety measures. Also, patients with a cemented prosthesis lose the crutches faster than those who have a knee surgery. The public hospital surgeons explained that only in specific cases, when patients don’t have any help at home or are very old, the hospital contacts a social centre to provide some more care to the patient after he is discharged from the hospital.

Lastly, the biggest complications that can happen in these types of surgeries are infection. The surgeon from the private hospital explained that infection can be treated with antibiotics and identified three more complications: thromboembolic problems, which can also be treated with antibiotics, dislocation and falling (a problem present in elders). The knee surgeon from the public hospital added the following complications: fracture and damaged vessel. He also added some information of the biggest problem that is infection. He explained that if the infection is acute, in the first days, the implant is washed, everything is changed and they wait for the infection to be solved. If the infection only appears some time after the surgery, the implant is taken out, a cement spacer with antibiotic is placed in the patient and after everything is controlled the patient is operated again. These complications were some of the ones identified by Ma (2014) in the list of complications that can take place after a hip or knee joint surgery.
Here is a summary of the above explanation:

**Table 21: Summary of Interviews to Orthopaedic Surgeons**

<table>
<thead>
<tr>
<th></th>
<th>Hip</th>
<th>Public</th>
<th>Knee</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Private</strong></td>
<td></td>
<td></td>
<td><strong>Private</strong></td>
<td></td>
</tr>
<tr>
<td>1) What is the main cause for hip and knee replacement surgeries?</td>
<td>Age</td>
<td>Age</td>
<td>Age</td>
<td>Age</td>
</tr>
<tr>
<td>2) What influences surgery duration?</td>
<td>Type of surgery</td>
<td>Type of prosthesis</td>
<td>Type of surgery</td>
<td>Type of prosthesis</td>
</tr>
<tr>
<td>3) What influences the length of stay after a Hip or Knee surgery?</td>
<td>Comorbidities</td>
<td>Weight</td>
<td>Intraoperative complications</td>
<td>Complications</td>
</tr>
<tr>
<td>4) What originates costs with these types of surgeries? Which factors weigh the most?</td>
<td>Implant</td>
<td>Human resources and their skills</td>
<td>Implant</td>
<td>Human resources and their skills</td>
</tr>
<tr>
<td>5) Which are the key factors to improve efficiency?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip</td>
<td>Knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>---------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Private</strong></td>
<td><strong>Public</strong></td>
<td><strong>Private</strong></td>
<td><strong>Public</strong></td>
<td></td>
</tr>
<tr>
<td>Surgeon’s technique/skill and experience</td>
<td>Reducing complications</td>
<td>Surgeon’s technique/skill and experience</td>
<td>Reducing time patient reaches operation room and enters Anaesthesia time</td>
<td></td>
</tr>
<tr>
<td>Good surgical programming</td>
<td></td>
<td>Good surgical programming</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>6) What are the approximate prices of the prosthesis?</strong></td>
<td><strong>7) How are prosthesis chosen for each patient?</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 € - 1 500 €</td>
<td>Protocols that depend on patient’s age</td>
<td>800 € - 1 000 €</td>
<td>Depends on patient’s age and bone health</td>
<td>Only one implant option</td>
</tr>
<tr>
<td>1 500 €</td>
<td>Depends on patient’s age and bone health</td>
<td>2 000 €</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>8) Which patient characteristics are analysed when choosing implants?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>Age</td>
<td>Age</td>
<td>Type of arthritis</td>
<td></td>
</tr>
<tr>
<td>Preoperative mobility capacity</td>
<td></td>
<td>Preoperative mobility capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>9) What types of prosthesis are used for people aged under 65 and for those aged 65 and over?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 65</td>
<td>&lt; 65</td>
<td>Protocol doesn’t depend only on age</td>
<td>Does not depend on age</td>
<td></td>
</tr>
<tr>
<td>&gt; 65 - &lt; 80</td>
<td>&gt; 65 - &lt; 70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 80</td>
<td>&gt; 70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>10) Do you feel there are differences in the way prosthesis are chosen in a public and a private hospital?</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Very similar</td>
<td>No</td>
<td>In public hospitals it has to do with prosthesis costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Private hospitals have more options</td>
<td></td>
</tr>
<tr>
<td><strong>11) Please describe how prosthesis are chosen.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIP</td>
<td>PUBLIC</td>
<td>HIP</td>
<td>PUBLIC</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
<td>-----</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td><strong>Private</strong></td>
<td><strong>Public</strong></td>
<td><strong>Private</strong></td>
<td><strong>Public</strong></td>
<td></td>
</tr>
<tr>
<td>Committee (doctors, administration) decides</td>
<td>Provision department decides</td>
<td>Committee (doctors, administration) decides</td>
<td>N/A (this doctor doesn’t participate in this and therefore doesn’t have knowledge on this matter)</td>
<td></td>
</tr>
<tr>
<td>Criterion: Price within high quality, logistics support</td>
<td>Criterion: Doctors’ list, price</td>
<td>Criterion: Price within high quality, logistics support</td>
<td>Frequency: Once a year</td>
<td></td>
</tr>
<tr>
<td>Frequency: Once a year</td>
<td>Frequency: Every 3 – 5 years</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

12) When choosing prosthesis are there any conflicts between doctors and administration?

- No
- Price is established in the regulation
- No
- N/A

13) Which factors weigh on the choice of prosthesis?

- Price
- Quality
- Replacement capacity
- Technical support
- Staff training

- Price
- Implant characteristics wanted by doctors
- Replacement capacity
- Technical support
- Staff training

- Price
- Quality
- Supplier guarantees and conditions offered

14) Would you like to choose a larger number of prosthesis?

- No, not necessary
- It would make no sense being able to choose more
- No, not necessary
- N/A

15) From the chosen prosthesis, what distinguishes them?

- Quality
- Price
- Supplier responsiveness

- Small quality differences.
- Supplier responsiveness

- Quality
- Price
- Supplier responsiveness

- N/A

16) Are there many differences in the results of the different types of implants?

- Yes, many
- No
- Yes, many
- What matters is that the surgery goes well
<table>
<thead>
<tr>
<th>Hip</th>
<th>Public</th>
<th>Knee</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>17) When is a revision necessary?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Mechanically put in a wrong way</td>
<td>– Depends on the use given to the implant, which depends on the patient’s weight and level of activity</td>
<td>– Mechanically put in a wrong way</td>
<td></td>
</tr>
<tr>
<td>– Allergies, infection</td>
<td></td>
<td>– Allergies, infection</td>
<td></td>
</tr>
<tr>
<td>– Bone loss</td>
<td></td>
<td>– Bone loss</td>
<td></td>
</tr>
<tr>
<td>18) How much does a revision surgery cost?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Much more expensive than a primary hip surgery</td>
<td>– It is twice the cost of a primary hip surgery</td>
<td>– Much more expensive than a primary knee surgery</td>
<td></td>
</tr>
<tr>
<td>– Technical error</td>
<td></td>
<td>– Wrong size</td>
<td></td>
</tr>
<tr>
<td>19) On average how much does a Total hip/knee surgery last? Have the number of years been increasing?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– 20 years on average</td>
<td>– Always above 10 years</td>
<td>– 20 years on average</td>
<td></td>
</tr>
<tr>
<td>– The number of years has been increasing</td>
<td>– The number of years hasn’t been increasing</td>
<td>– The number of years has been increasing</td>
<td></td>
</tr>
<tr>
<td>20) Do you have secondary hospitals to take care of the patients when they are discharged? Where do the majority of patients go?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Patients go home using crutches</td>
<td>– Only in the case they live alone or are very old, do we give them support</td>
<td>– Patients go home using crutches</td>
<td></td>
</tr>
<tr>
<td>– Must have houses prepared</td>
<td></td>
<td>– 2 crutches during the 1st month and only 1 crutch during 1 to 3 months</td>
<td></td>
</tr>
<tr>
<td>21) Which are the biggest complications that can take place in these types of surgeries?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>– Infection</td>
<td>– Infection</td>
<td>– Infection</td>
<td></td>
</tr>
<tr>
<td>– Thromboembolic problems</td>
<td></td>
<td>– Thromboembolic problems</td>
<td></td>
</tr>
<tr>
<td>– Dislocation and falling</td>
<td></td>
<td>– Dislocation and falling</td>
<td></td>
</tr>
</tbody>
</table>

Source: Own Elaboration, Interviews 2015
6.2.3 Questionnaires to Nurses

One nurse from each hospital was interviewed. We found this important because nurses are the clinical staff that, to our knowledge, spends most time with patients. Below are the main conclusions we reached.

In the public hospital the nurse to whom we spoke, informed us that they aren’t aware of the time patients spend in surgery, but they have knowledge of the length of stay (moment since a patient is admitted until being released). The factors that influence most the length of stay are the cases with complications, infection (which is in most cases only detected after hospitalization phase) and the rehabilitation process. When nurses teach and execute some exercises related to self-care taking they are able to achieve better results and reduce the length of stay. When this isn’t done patients leave the hospital with a much higher dependence level and hospitalization time increases due to the lack of independence and autonomy.

In the private hospital the nurse that we interviewed feels that the time a patient is in surgery is directly influenced by patient’s hemodynamic/anaesthetic conditions; this is the lower the anaesthetic risk, the smaller the time the anaesthetic team will take preparing the patient for surgery. In addition, time is also influenced by the surgeon’s experience and the experience with the prosthesis being implanted. The third and last factor is the risks and surgical complications inherent to any surgery.

Both nurses explained the importance of educating patients about the risks inherent to a total hip surgery. It is very important to teach and show patients the correct movements, positions and behaviours in order to prevent the dislocation of the new implant, something even more common due to the new techniques. In addition, patients are also taught exercises that promote their autonomy, such as moving from a chair to the bed and vice versa and starting to walk. Finally, they are also taught about special cares to have at home such as how to remove carpets and the kind of shoes that are adequate.
Special care and education is also necessary for patients who undergo a total knee surgery.

In the public hospital they make an effort to start mobilizing patients and performing specific exercises (isometric exercises with muscular contractions and assisted exercises in bed, in a chair and standing) as early as possible in order to diminish the length of stay. Another strategy used is having an appointment prior to the surgery where a lot of the information on the recovery phase is explained to the patients. This is a way of achieving good results, reduction in the length of stay and in anxiety.

In the private hospital, the nurse explained how crucial it is that patients follow doctor’s recommendations in terms of the time using weight with and without crutches and the amount of time doing physiotherapy (with or without the help of a professional).

From this point onwards we only have the answers from the nurse of Centro Hospitalar do Porto (public hospital) because unfortunately the other nurse, from the private hospital, did not answer the following questions.

Nurses’ role is definitely very important and has a large impact on patients’ length of stay.

The generalist nurse is 24h with the patient. It is him who answers all questions, even after a teaching period done in the morning or during the afternoon. It is very important that patients are accompanied, that the team is tuned and that all information is given to promote a continuous improvement of the patient so that recovery is as fast as possible. Nurses have conscious of the fact that the longer patients are hospitalized, the higher are costs and so an effort must be made in order to try and make this service economically sustainable.

Nurses feel that patients really like receiving information and education on the surgery and recovery period. The Portuguese population is characterized as being very particular. A few years ago people didn’t really care about the treatment they were
going to receive and would let doctors decide about everything. Today the population is more interested in their own health; they perform research on websites, documents and relevant articles and want to be more participative in the treatment and nurses help them in this sense.

One or two days after a patient has been hospitalized, nurses question them about the necessities they have at home in terms of family help and logistics. If necessary, social assistants also help patients with questions of this matter. In the case of hip or knee programmed surgeries this issue has been resolved in a previous appointment. In most cases patients leave off to their homes and in only very few cases do they lack support at home. In the case of specific clinical relevant criteria that have to do with the recovery of the patient, patients are sent to a unit of continuous care, a physiotherapy clinic or a unit of physiatry in a hospital.

The nurses’ role since the moment the patient enters the hospital until leaving is extremely important; they are the patients’ protectors. They start by running an evaluation of the patient’s necessities, context, medication and recovery potential. Throughout hospitalization, the nurse educates and informs the patient about the pre and post-operative matters and helps him create adaptive strategies to his condition. Many times nurses use and include patient’s families for the activities and exercises that will be needed and performed at home.

To help with all the education nurses give to patients, the service has synthesized pamphlets one for hip surgeries and another for knee surgeries, that were written and prepared by professionals. These pamphlets have all the necessary information on the patient’s course, risks, indications and counter-indications of the surgery and some useful contacts. These are handed out to the patients during their appointment before the surgery, but some lose or forget these documents and therefore nurses repeat the information or even reprint the pamphlet. Nurses must be conscious that these are the base documents.
In terms of the time a patient takes to recover from a hip or knee surgery, in general terms the first one takes between 7 and 9 days and the second one between 5 and 7 days. However, this depends on the patient’s characteristics. On one hand, more and more we have an ageing population, with associated comorbidities that makes a quick recovery more difficult. On the other hand we also have younger people going through these surgeries, which lowers our average value since they can recover much faster.

Recovery from hip surgery takes, on average, longer than recovery from a knee surgery because it has some positioning and movement restrictions and the process of starting to walk is slower. Also, on average, patients who need a total hip surgery are older than the ones that put a knee implant.

In revision surgeries, nurses play the same role in what concerns the basic principals. The difference here is that nurses must be aware that the level of aggression is higher in these cases and therefore a patient might need to stay one or two more days recovering in hospital, before leaving.

In terms of costs, nurses can help diminish these during hospitalization. If there is a general conscience for this the use of clinical consumables may be decreased. Nurses play an important role here and if they know what is used per month and which products are used in bigger quantities, they can help to decrease their usage as much as possible. Having conscious of what is being used is very important.

In total hip and knee surgeries, the bigger complications are infections because they lead to re-internments that will need antibiotics, peripheral intravenous thrombosis or the shortening of the implant. All of these complications are very infrequent, they happen only in about 1% of the cases. We are between or even below the average.
7 Conclusions

7.1 General Conclusions

From our work and summing up the answers to our research questions, we can conclude that there are cost variations in total hip and knee replacement surgeries, both within and across the two Portuguese hospitals we analysed.

We found out that, 84.4% of total cost variance in hip surgeries is explained by variances in hospital, gender, length of stay, age and implant cost. All variables are statistically significant, with the exception of gender. In terms of knee surgeries 85.8% of total cost variance is explained by the model and the remaining conclusions were the same.

As we have seen, throughout our study, total costs are composed by three types of costs: implant, operating room and hospitalization costs. On average terms, in both hospitals and for both types of surgeries, the implant cost is not the one with the largest weight.

Hip and knee implants are physician preferred items in the Portuguese hospitals we studied. Each hospital has a team composed of doctors and other staff that together make their choices. They are happy with the system, their goals are aligned and conflict does not seem to exist.

7.2 Implications of our Study for Managers and Political Decision Makers

Our study is a starting point for managers and doctors who work in Portuguese hospitals. With our work we were able to at least show how much can be done in the future to increase cost control in health organizations, which are crucial for the well being of the Portuguese population.

We did an effort to spread more knowledge on where costs come from in the orthopaedic and surgery department and how much each decision taken by doctors and
managers can affect hospital costs. The more information these actors have access to the easier it will be for decision-making.

Hopefully, with our methodology, conclusions and discussions a greater interest and criticism about this area will grow, leading to more investigation, discovery and knowledge.

### 7.3 Limitations of our Study

Our study had some limitations.

Firstly, we are comparing two hospitals that are very different in the way they operate, mainly due to the fact that the public hospital is a training hospital for students in medical schools. This difference impacts costs related to human resources and consumables. Labour costs in the public hospital will be lower than in the private hospital, since students are paid much lower wages than experienced hospitals. In terms of clinical consumables, the public hospital probably uses more than the private one due to its teaching character.

Secondly, not being able to know the brand and names of the implants used in the public hospital, did not let us compare costs, between the same implants, and therefore limited our exact understanding of implant cost variations between both hospitals.

Thirdly, as we were not granted access to the original costs accounting documents from the private hospital, we do not know exactly how they reached their costs. These were explained to us verbally. On the other hand, the public hospital conceded us those documents. Also, the private hospital includes the replacement of some prosthesis components in the same list as total hip and knee replacement surgeries.

In addition, both hospitals did not concede access to patient’s weight, medication and complications and information about the doctors, which did each surgery. This type of information would have been very useful in terms of the richness of our conclusions and
would have permitted us to compare and link to studies we analysed in the literature review.

Lastly, the usage of the operating room is not exactly the same in both hospitals. On one hand the public hospital has surgery rooms allocated only for orthopaedic surgeries whilst the private hospital does not make this separation.

### 7.4 Recommendations for Further Investigation

For further investigation, we recommend a study on total hip and knee surgery costs that includes a larger number of hospitals and data from a larger number of years, so that results would be more accurate. Including hospitals in these studies seems to be a great way to access information related to costs and all the variables, which impact them.

Understanding what other factors, other than the type of hospital, gender, type of surgery and age impact on cost variations would be extremely useful. One of the variables which would be very interesting to include, and which we were not able to, is the patient’s weight, since it is considered a factor with a strong impact on the demand for these types of surgeries. With this it would also be interesting to understand if excessive weight has any impact on the time a patient takes to recover and therefore if it has any impact on hospitalization costs. Another variable that would be very interesting to include would be patient’s comorbidities. Accessing this information would also let us understand how much this affects patient’s recovery speed and therefore the impact it has, once again, on hospitalization costs. In addition, the exact diagnosis for each case, patient level of input in decision making and implant choice, complications, discharge destination, method of payment and the differences in the price charged by different manufacturers would certainly be very interesting. Also, having information on the doctors that performed each surgery would enable us to understand their impact on costs. Furthermore, as referred above, including many hospitals would make other factors, such as the number of beds, annual procedure volume and teaching status, very curious to analyse.
We also think that a deeper study into the implant suppliers and the industry itself, in Portugal, would be very interesting since our analysis is quite limited.

In addition, continual gathering and registering information on the long-term results, quality of the implants and QALY gained in hip, knee and revision joint surgeries would be very useful for future assessments in terms of implant choice, not only on the product itself but also in terms of costs. This would also permit a creation of standards for product choice of Physician Preferred Items.
8 Bibliography


Wise, P. (2014), “About investment in Portugal”, [http://www.ft.com/cms/s/0/6dabfb0c-44be-11e4-ab0c-00144feabdc0.html - axzz3OnUGJr4c](http://www.ft.com/cms/s/0/6dabfb0c-44be-11e4-ab0c-00144feabdc0.html - axzz3OnUGJr4c), accessed in January, 14, 2015.
9 Annexes

9.1 Questionnaire to Surgeons

1. What are the main causes for hip and knee replacement surgeries?
2. What influences surgery duration?
3. What influences length of stay after a Hip or Knee surgery?
4. What originates costs with these types of surgeries? Which factors weigh the most?
5. Which are the key factors to improve efficiency?
6. What are the approximate prices of the prosthesis?
7. How are prosthesis chosen for each patient?
8. Which patient characteristics are analysed when choosing the implant?
9. What types of prosthesis are used for people aged under 65 and for those aged 65 and over?
10. Do you feel there are differences in the way prosthesis are chosen in a public and a private hospital?
11. Please describe how prosthesis are chosen.
12. When choosing prosthesis are there any conflicts between doctors and administration?
13. Which factors weigh on the choice of prosthesis?
14. Would you like to choose a larger number of prosthesis?
15. From the chosen prosthesis, what distinguishes them?
16. Are there many differences in the results of the different types of implants?
17. When is a revision necessary?
18. How much does a revision surgery cost?
19. On average how much does a Total hip/knee surgery last? Have the number of years been increasing?
20. Do you have secondary hospitals to take care of the patients when they are discharged? Where do the majority of patients go?
21. Which are the biggest complications that can take place in these types of surgeries?

9.2 Questionnaire to Nurses

1. What influences surgery duration in a total hip and knee surgery? (If it is different for each case, please separate your answers)
2. Please give me examples of the types of special cares patients, which have undergone a total hip implant surgery, should have? Is there any moment for patient training and how is it done?
3. Please give me examples of the types of special cares patients, which have undergone a total knee implant surgery, should have? Is there any moment for patient training and how is it done?
4. In your opinion, are nurses’ roles very important and does it have a large impact on patients’ length of stay?
5. In psychological terms, do patients like to be accompanied and receive information from nurses?
6. When doctors discharge patients, do they normally go home or is there any support centre?
7. Please explain in a detailed way nurses’ role since the moment a patient enters until he leaves the hospital.
8. The advice and support given by nurses to patients who have gone through a knee surgery are different or the same as those given to who has gone through a hip surgery?
9. What is the time of recovery for a patient who has gone through a total knee surgery?
10. What is the time of recovery for a patient who has gone through a total hip surgery?
11.
12. Does recovery take more time for patients who have gone through a hip surgery? If so, please explain why.
13. Are nurses’ roles the same in a primary and a revision surgery?
14. In your opinion, how can nurses help reduce costs?
15. In your opinion, do nurses have an important role in helping to reduce costs?
16. Which are the main complications in these types of surgeries?
17. From these complications, which one is the most frequent?

9.3 Questionnaire to Implant Suppliers

1. Who are the main companies selling hip and knee implants in Portugal?
2. How much market share does each one have?
3. How do you describe the market at the moment?
4. In what way do doctors influence the purchasing of knee and hip implants? Can doctors chose the type of implant they want to use or do hospitals purchase only one type of implant that must be used by all professionals?
5. When choosing an implant, which are the factors hospitals value the most?
6. Are there any hospitals in which the type of implant used depends on patient's characteristics?
7. Which type of implant has greater demand?
8. Do implants vary in terms of quality and effectiveness or are these equally guaranteed in all, regardless the price?
9. Are there confidentiality clauses for the prices at which implants are sold?
10. Do implant prices vary from hospital to hospital?
11. Are prices different between public hospitals?
12. Are prices different between private hospitals?
13. And between public and private ones?
14. Are there any differences between hospitals when choosing between implants?
15. Are there any hospitals in which the type of implant used depends on patient's characteristics?
9.4 Detailed Inferential Statistics

Equality of Means Test

Hip Implant Cost

Hospital

For a 5% significance level

\[ H_0: \mu_{\text{Private}} = \mu_{\text{Public}} \]
\[ H_1: \mu_{\text{Private}} \neq \mu_{\text{Public}} \]

1) Levene Test for equal variances

\[ H_0: \sigma^2_{\text{Private}} = \sigma^2_{\text{Public}} \text{ (Equal variances assumed)} \]
\[ H_1: \sigma^2_{\text{Private}} \neq \sigma^2_{\text{Public}} \text{ (Equal variances not assumed)} \]

If \( P_{\text{Value}} < \alpha \), we reject \( H_0 \)

If \( P_{\text{Value}} \geq \alpha \), we do not reject \( H_0 \)

In this case, \( P_{\text{Value}} = 0.000 < \alpha = 0.05 \), so we reject \( H_0 \) and therefore variances are different
2) T-test for Equality of Means

Sig = 0.000 < \alpha = 0.05, so we reject \textit{H}_0, this is the means (\mu_{\text{Private}} and \mu_{\text{Public}}) are significantly different and therefore based on the sample we can affirm that \mu_{\text{Private}} > \mu_{\text{Public}} with 95% of confidence.

**Gender**

For a 5% significance level

\textit{H}_0: \mu_{\text{Female}} = \mu_{\text{Male}}

\textit{H}_1: \mu_{\text{Female}} \neq \mu_{\text{Male}}

1) Levene Test for equal variances

\textit{H}_0: \sigma^2_{\text{Female}} = \sigma^2_{\text{Male}} (Equal variances assumed)

\textit{H}_1: \sigma^2_{\text{Female}} \neq \sigma^2_{\text{Male}} (Equal variances not assumed)

If \textit{P}_{\text{Value}} < \alpha, we reject \textit{H}_0

If \textit{P}_{\text{Value}} \geq \alpha, we do not reject \textit{H}_0

In this case, \textit{P}_{\text{Value}} = 0.087 > \alpha = 0.05, so we do not reject \textit{H}_0 and therefore variances are equal.
2) T-test for Equality of Means

Sig = 0.087 > α = 0.05, so we do not reject H₀, this is the means (μ_Female and μ_Male) are equal with 95% of confidence.

Knee Implant Cost

Hospital

For a 5% significance level

H₀: μ_Private = μ_Public

H₁: μ_Private ≠ μ_Public

1) Levene Test for equal variances

H₀: σ²_Private = σ²_Public (Equal variances assumed)

H₁: σ²_Private ≠ σ²_Public (Equal variances not assumed)

If P_Value < α, we reject H₀

If P_Value ≥ α, we do not reject H₀
In this case, $P_{\text{Value}} = 0.000 < \alpha = 0.05$, so we reject $H_0$ and therefore variances are different.

2) T-test for Equality of Means

$\text{Sig} = 0.000 < \alpha = 0.05$, so we reject $H_0$, this is the means ($\mu_{\text{Private}}$ and $\mu_{\text{Public}}$) are significantly different and therefore based on the sample we can affirm that $\mu_{\text{Private}} > \mu_{\text{Public}}$ with 95% of confidence.

**Gender**

For a 5% significance level

$H_0$: $\mu_{\text{Female}} = \mu_{\text{Male}}$

$H_1$: $\mu_{\text{Female}} \neq \mu_{\text{Male}}$

1) Levene Test for equal variances

$H_0$: $\sigma^2_{\text{Female}} = \sigma^2_{\text{Male}}$ (Equal variances assumed)

$H_1$: $\sigma^2_{\text{Female}} \neq \sigma^2_{\text{Male}}$ (Equal variances not assumed)

If $P_{\text{Value}} < \alpha$, we reject $H_0$

If $P_{\text{Value}} \geq \alpha$, we do not reject $H_0$
In this case, $P_{\text{value}} = 0.426 > \alpha = 0.05$, so we do not reject $H_0$ and therefore variances are equal.

2) T-test for Equality of Means

$\text{Sig} = 0.426 > \alpha = 0.05$, so we do not reject $H_0$, this is the means ($\mu_{\text{Female}}$ and $\mu_{\text{Male}}$) are equal with 95% of confidence.

**Estimating Model – Linear Regression Model**

To answer our first research question – Are implant costs the main factor affecting the total cost variation in total hip and knee replacement surgeries? – we are now going to understand how the variance in the total cost, in hip and knee surgeries, is explained by the model, in this case by the hospital, gender, length of stay, age and implant cost.

**Model 1 – Total Cost of Hip Surgeries**

Total Cost $i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{AvgLS}_i + \beta_4 \text{Age}_i + \beta_5 \text{ImpC}_i + \mu_i$

$\mu_i =$ error

Estimated Model:

$\hat{\text{Total Cost}}_i = 1326.7 - 1351.0 \, \text{Hosp}_i + 9.7 \, \text{Gend}_i + 212.4 \, \text{AvgLS}_i + 15.6 \, \text{Age}_i + 1.1 \, \text{ImpC}_i$

Coefficient of Determination (model quality indicator): $R^2 = 0.844$
This means that 84.4% of total cost variance is explained by the model, this is by variances in hospital, gender, length of stay, age and implant cost.

**Global Significance Test**

Total Cost \(_i\) = \(\beta_0 + \beta_1 \text{ Hosp}_i + \beta_2 \text{ Gend}_i + \beta_3 \text{ AvgLS}_i + \beta_4 \text{ Age}_i + \beta_5 \text{ ImpC}_i + \mu_i\)

\(H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0 \rightarrow \text{Model is not significant; none of the variables influence total cost significantly}\)

\(H_1 : \beta_1 \neq 0 \lor \beta_2 \neq 0 \lor \beta_3 \neq 0 \lor \beta_4 \neq 0 \lor \beta_5 \neq 0 \lor \beta_6 \neq 0 \rightarrow \text{Model is globally significant, this is at least one of the variables is significant}\)

\(P_{\text{Value}} = \text{Sig}\)

\(\text{Sig} = 0.000 < \alpha = 0.05\)

For \(\alpha = 5\%\) we reject \(H_0\) and therefore the model is globally significant.

**Individual Significance Test**

We are now going to test which variables are actually relevant to explain total cost.

Total Cost \(_i\) = \(\beta_0 + \beta_1 \text{ Hosp}_i + \beta_2 \text{ Gend}_i + \beta_3 \text{ AvgLS}_i + \beta_4 \text{ Age}_i + \beta_5 \text{ ImpC}_i + \mu_i\)
H₀ : β₁ = 0 → The variable Hospital is not significant, this is total cost does not depend on the type of hospital

H₁ : β₁ ≠ 0 → The variable Hospital is significant, this is total cost depend on the type of hospital

Sig = 0.000 < α = 0.05

For a 5% significance level we reject H₀ and this means that the variable hospital is statistically significant.

Looking at the remaining variables, only gender is not statistically significant, Sig = 0.926, which means that total cost does not depend on gender or there is no significant difference between total cost with men and women.

Relating to our first research question we can start by affirming that implant costs are statistically significant. This means that it has an impact on total cost variations, but isn’t the only one and we cannot say if this variable is more or less significant than the others (hospital, length of stay, age).

Coefficient Interpretation

**Table 22: Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 – Public</th>
<th>0 – Private</th>
<th>2 – Female</th>
<th>0 – Male</th>
</tr>
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<tbody>
<tr>
<td>Hospital</td>
<td>1 – Public</td>
<td>0 – Private</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>2 – Female</td>
<td>0 – Male</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
\( \beta_1 = -1351.0 \Rightarrow \) Estimated difference between the mean total cost of public and private hospitals, maintaining all rest constant. It is estimated that in public hospitals the mean total cost is 1,351.0 € below the mean total cost in private hospitals, once again keep all rest constant.

\( \beta_2 = 9.7 \Rightarrow \) Estimated difference between the mean total cost with women and men, maintaining all rest constant. Nonetheless, this difference did not reveal to be statistically significant (\( P_{\text{value}} = 0.926 > \alpha = 0.05 \))

\( \beta_3 = 212.4 \Rightarrow \) It is estimated that, on average, when the number of hospitalization days increases by 1, total cost increases by 212.4 €, ceteris paribus. This means that for every additional day a patient is hospitalized total cost increases on average by 212.4 €.

\( \beta_4 = 15.6 \Rightarrow \) It is estimated that, on average, when patient’s age increases by 1 year, total cost increases by 15.6 €, keeping all rest constant.

\( \beta_5 = 1.1 \Rightarrow \) It is estimated that, on average, when implant cost increases by 1 €, total cost increases by 1.1 €, keeping all rest constant.

**Model 2 – Total Cost of Knee Surgeries**

We are now going to understand how the variance in the total cost, in knee surgeries, is explained by the model, in this case by the hospital, gender, length of stay, age and implant cost.
Total Cost \_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{AvgLS}_i + \beta_4 \text{Age}_i + \beta_5 \text{ImpC}_i + \mu_i

\mu_i = \text{error}

Estimated Model:

^\wedge
\text{Total Cost}_i = 1726.6 - 1448.4 \text{Hosp}_i - 43.8 \text{Gend}_i + 211.4 \text{AvgLS}_i + 11.6 \text{Age}_i + 1.0 \text{ImpC}_i

Coefficient of Determination (model quality indicator): R^2 = 0.858

This means that 85.8% of total cost variance is explained by the model, this is by variances in hospital, gender, length of stay, age and implant cost.

Global Significance Test

\text{Total Cost}_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{AvgLS}_i + \beta_4 \text{Age}_i + \beta_5 \text{ImpC}_i + \mu_i

H_0 : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0 \rightarrow \text{Model is not significant; none of the variables influence total cost significantly}

H_1 : \beta_1 \neq 0 \lor \beta_2 \neq 0 \lor \beta_3 \neq 0 \lor \beta_4 \neq 0 \lor \beta_5 \neq 0 \lor \beta_6 \neq 0 \rightarrow \text{Model is globally significant, this is at least one of the variables is significant}

P_{\text{value}} = \text{Sig}

\text{Sig} = 0.000 < \alpha = 0.05

For \alpha = 5\% we reject H_0 and therefore the model is globally significant.
Individual Significance Test

We are now going to test which variables are actually relevant to explain total cost.

Total Cost_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{AvgLS}_i + \beta_4 \text{Age}_i + \beta_5 \text{ImpC}_i + \mu_i

H_0 : \beta_1 = 0 \rightarrow \text{The variable Hospital is not significant, this is total cost does not depend on the type of hospital}

H_1 : \beta_1 \neq 0 \rightarrow \text{The variable Hospital is significant, this is total cost depend on the type of hospital}

Sig = 0.000 < \alpha = 0.05

For a 5% significance level we reject H_0 and this means that the variable hospital is statistically significant.

Looking at the remaining variables, only gender is not statistically significant, Sig = 0.614, which means that total cost does not depend on gender or there is no significant difference between total cost with men and women.

To answer our first research question ‘Are implant costs the main factor affecting the total cost variation in total hip and knee replacement surgeries?’ we can start by affirming that implant costs are statistically significant. This means that it has an impact on total cost variations, but isn’t the only one and we cannot say if this variable is more or less significant than the others (hospital, length of stay, age).
Coefficient Interpretation

Table 23: Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 – Public</th>
<th>0 – Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>3 – Female</td>
<td>0 – Male</td>
</tr>
</tbody>
</table>

^ \( \beta_1 = -1448.4 \) \rightarrow Estimated difference between the mean total cost of public and private hospitals, maintaining all rest constant. It is estimated that in public hospitals the mean total cost is 1448.4 € below the mean total cost in private hospitals, once again keep all rest constant.

^ \( \beta_2 = -43.8 \) \rightarrow Estimated difference between the mean total cost with women and men, maintaining all rest constant. Nonetheless, this difference did not reveal to be statistically significant (\( P_{value} = 0.614 > \alpha = 0.05 \))

^ \( \beta_3 = 211.4 \) \rightarrow It is estimated that, on average, when the number of hospitalization days increases by 1, total cost increases by 211.4 €, ceteris paribus. This means that for every additional day a patient is hospitalized total cost increases on average by 211.4 €.

^ \( \beta_4 = 11.6 \) \rightarrow It is estimated that, on average, when patient’s age increases by 1 year, total cost increases by 11.6 €, keeping all rest constant.

^ \( \beta_5 = 1.0 \) \rightarrow It is estimated that, on average, when implant cost increases by 1 €, total cost increases by 1 €, keeping all rest constant.
As explained before, in Variability in Costs Associated with Total Hip and Knee Replacement Implants, by Robinson et al., 2012, the variation in device costs in hip and knee surgeries is attributed to patient characteristics (age, diagnoses, comorbidities, complications, discharge destination, insurance coverage vs. Medicare), hospital characteristics (number of beds, annual procedure volume, teaching status) and within-hospital variation (physician specific preferences in terms of device choice, differences in the price charged by different manufacturers).

Of the above factors we just had access to age and hospital characteristics. With the data we had access to we are now going to understand how the variance in the implant cost in hip surgeries is explained by our model, in this case by the hospital, gender and age.

**Model 3 – Implant Cost of Hip Surgeries**

\[
\text{Implant Cost}_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{Age}_i + \mu_i
\]

\[
\mu_i = \text{error}
\]

Estimated Model:

\[
^\wedge \\
\text{Implant Cost}_i = 2161.9 - 788.9 \text{Hosp}_i + 46.5 \text{Gend}_i - 4.6 \text{Age}_i
\]

Coefficient of Determination (model quality indicator): \( R^2 = 0.274 \)

This means that only 27.4% of implant cost variance is explained by the model, this is by variances in hospital, gender and age.
Global Significance Test

Implant Cost \( i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{Age}_i + \mu_i \)

\( H_0 : \beta_1 = \beta_2 = \beta_3 = 0 \rightarrow \) Model is not significant; none of the variables influence implant cost significantly

\( H_1 : \beta_1 \neq 0 \lor \beta_2 \neq 0 \lor \beta_3 \neq 0 \rightarrow \) Model is globally significant, this is at least one of the variables is significant.

\( P\text{Value} = \text{Sig} \)

\( \text{Sig} = 0.000 < \alpha = 0.05 \)

For a 5% significance level we reject \( H_0 \) and therefore the model is globally significant.

Individual Significance Test

We are now going to test which variables are actually relevant to explain implant cost.

Implant Cost \( i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{Age}_i + \mu_i \)

Hospital

\( H_0 : \beta_1 = 0 \rightarrow \) The variable Hospital is not significant, this is implant cost does not depend on the type of hospital
\( H_1: \beta_1 \neq 0 \rightarrow \) The variable Hospital is significant, this is implant cost depend on the type of hospital

\( \text{Sig} = 0.000 < \alpha = 0.05 \)

For a 5% significance level we reject \( H_0 \) and this means that the variable hospital is statistically significant.

Looking at the remaining variables, they are all not statistically significant, which means that implant cost does not depend on gender and age or there is no significant difference between implant cost between men and women and different ages.

Coefficient Interpretation

Table 24:Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 – Public</th>
<th>0 – Private</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital</td>
<td>4 – Female</td>
<td>0 – Male</td>
</tr>
</tbody>
</table>

\( ^\wedge \)

\( \beta_1 = – 788.9 \rightarrow \) Estimated difference between the mean implant cost of public and private hospitals, maintaining all rest constant. It is estimated that in public hospitals the mean implant cost is 788.9 € below the mean implant cost in private hospitals, once again keeping all rest constant.
\( \beta_2 = 46.5 \rightarrow \) Estimated difference between the mean implant cost between women and men, maintaining all rest constant. Nonetheless, this difference did not reveal to be statistically significant (P\text{ value} = 0.514 > \alpha = 0.05).

\( \beta_3 = -4.6 \rightarrow \) It is estimated that, on average, when patient’s age increases by 1 year, implant cost decreases by 4.6 €, keeping all rest constant. Nonetheless, this difference did not reveal to be statistically significant (P\text{ value} = 0.085 > \alpha = 0.05).

**Model 4 – Implant Cost of Knee Surgeries**

We are now going to understand how the variance in the implant cost in knee surgeries is explained by the model, in this case by the hospital, gender and age.

\[
\text{Implant Cost}_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{Age}_i + \mu_i
\]

\( \mu_i = \text{error} \)

Estimated Model:

\[
\text{Implant Cost}_i = 1431.6 - 186.8 \text{Hosp}_i + 23.0 \text{Gend}_i - 0.1 \text{Age}_i
\]

Coefficient of Determination (model quality indicator): \( R^2 = 0.053 \)

This means that only 5.3% of implant cost variance, in knee surgeries, is explained by the model, this is by variances in hospital, gender and age.
Global Significance Test

Implant Cost \(_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{Age}_i + \mu_i\)

\(H_0 : \beta_1 = \beta_2 = \beta_3 = 0 \rightarrow \text{Model is not significant; none of the variables influence implant cost significantly}\)

\(H_1 : \beta_1 \neq 0 \lor \beta_2 \neq 0 \lor \beta_3 \neq 0 \rightarrow \text{Model is globally significant, this is at least one of the variables is significant}\)

\(P\text{ Value} = \text{Sig}\)

\(\text{Sig} = 0.000 < \alpha = 0.05\)

For a 5\% significance level we reject \(H_0\) and therefore the model is globally significant.

Individual Significance Test

We are now going to test which variables are actually relevant to explain implant cost.

Implant Cost \(_i = \beta_0 + \beta_1 \text{Hosp}_i + \beta_2 \text{Gend}_i + \beta_3 \text{Age}_i + \mu_i\)

Hospital

\(H_0 : \beta_1 = 0 \rightarrow \text{The variable Hospital is not significant, this is implant cost does not depend on the type of hospital}\)
$H_1 : \beta_1 \neq 0 \rightarrow$ The variable Hospital is significant, this is implant cost depend on the type of hospital

$\text{Sig} = 0.000 < \alpha = 0.05$

For a 5% significance level we reject $H_0$ and this means that the variable hospital is statistically significant.

Looking at the remaining variables, they are all not statistically significant, which means that implant cost does not depend on gender and age or there is no significant difference between implant cost between men and women and different ages.

Coefficient Interpretation

Table 25: Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>1 – Public</th>
<th>0 – Private</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
</tr>
<tr>
<td>Gender</td>
<td>5 – Female</td>
<td>0 – Male</td>
</tr>
</tbody>
</table>

$^\wedge$

$\beta_1 = -186.8 \rightarrow$ Estimated difference between the mean implant cost of public and private hospitals, maintaining all rest constant. It is estimated that in public hospitals the mean implant cost is 186.8 € below the mean implant cost in private hospitals, once again keeping all rest constant.
\[ \beta_2 = 23.0 \rightarrow \text{Estimated difference between the mean implant cost between women and men, maintaining all rest constant. Nonetheless, this difference did not reveal to be statistically significant (} P_{\text{value}} = 0.634 > \alpha = 0.05). \]

\[ \beta_3 = -0.1 \rightarrow \text{It is estimated that, on average, when patient’s age increases by 1 year, implant cost decreases by 0.1 }\] €, keeping all rest constant. Nonetheless, this difference did not reveal to be statistically significant (\( P_{\text{value}} = 0.978 > \alpha = 0.05). \]

As explained before, the private hospital uses many different implants for hip surgeries and knee surgeries that differ in price not only between the different ones but also between equivalent ones. In the public hospital it is different; there are 3 different types of hip implants, each type has a price and only 1 type of knee implant with only one price.

From the questionnaires to surgeons we were informed that the type of implants used in patients younger than 65 are generally more expensive than those used in older patients. In both hip and knee total cost models we can see that this is the tendency, but still the differences did not reveal to be statistically significant.