Master thesis

Master of Science (M.Sc.) Health Sciences - Optimization of healthcare processes

Health Technology and Services Research (HTSR)

Impact of a value-oriented care purchasing process for total joint arthroplasty

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Preface

This study presents the thesis done for my graduation project for the master Health Sciences with a specialization in optimization of healthcare processes at the University of Twente. I have performed my thesis at Company X, and I have learned a lot by doing the master thesis in a health insurance company.

First, I would like to thank my first supervisor Dr. Erik Koffijberg for his help especially with the analysis and critical feedback. I would also like to thank my second supervisor Dr. Michelle Kip for her useful feedback. I would also like to thank Y for making the data available for my research and all people from the department MSZ for answering my questions. I am very thankful that Company X gave me the opportunity to conduct this interesting research in one of the largest insurance company in the Netherlands.

I hope you will enjoy reading this thesis.

Marli Leus

Abstract

Background: Healthcare expenditures in the Netherlands increase by an average of 2,9 percent per year. As a result, the healthcare system is challenged by a need to rationalize resources and to improve efficiency and effectiveness. At this moment, many inefficiencies exist in healthcare. The principal goal is to look carefully at what sensible care is for patients. This can be done by looking at the value of patient care. This means health outcomes achieved which matter to patients per euro spent to achieve those outcomes. Company X has developed a value-orientated care purchasing process, based on principles of VBHC. The main goals of this process are to maximize value of patient care, increase quality of care and reduce healthcare costs. At this moment, there exists limited evidence of actual cost savings and quality improvements due to introduction of value-added programs. Therefore, this study will try to assess if the value-oriented care purchasing process (VOP) for knee and hip arthroplasty developed at Company X contributes to a higher value of healthcare

Methodology: The research methods consisted of two steps. First a mini-literature review was performed to identify relevant outcome and cost measures for knee and hip arthroplasty. Outcome measures that were selected are: readmissions, revisions, and infections. Cost measures were hospital days, imaging activities and outpatient visits. Data is used from an existing database within Company X. For readmission, revision and infections, logistic regression was used to identify the effect of VOP on selected outcomes. A multilevel analysis was used to identify the effect of VOP on hospital days, imaging activities and outpatient visits.

Results: In total, 3858 hip arthroplasty patients and 3866 knee arthroplasty patients were included. Effect sizes of VOP hospitals on outcomes and costs are varying between 4,6% and 59,4% but are all non-significant. Results for knee arthroplasty show that patients treated in a participating hospital have a 38% lower chance of revisions and 8,6% lower chance of having more than three outpatient visits but have a 27,4% higher chance of readmissions, 24,4% higher chance of infections, 37% higher chance of more than five hospital days after knee arthroplasty and a 33,4% higher chance of having more than two imaging activities. For hip arthroplasty, results show that patients treated in a participating hospital have a 4,6% lower chance of having more than three outpatient visits, but experience a 10,3% higher chance of readmissions, 23,1% higher chance of revisions, 59,4% higher chance of infections, 52,5% higher chance of more than five hospital days after hip arthroplasty and a 16% higher chance of having more than two imaging activities.

Conclusion: This study did not find improvements in outcomes and costs measures with available data at this moment for knee and hip arthroplasty after the introduction of VOP. Before making a decision about implementing VOP for other conditions, it is suggested to examine the effects of VOP for a longer period of time, to include qualitative outcome measures and to obtain data from the total knee and hip arthroplasty care pathway including rehabilitation.

Content

1. Introduction

This chapter provides background information, information about the value-oriented care purchasing process, problem formulation, objective, and research question of this study. At the end of the chapter the structure of this report will be described in the reading guide.

1.1 Background information

Healthcare expenditures in the Netherlands increase by an average of 2,9 percent per year. Healthcare expenditures per person grow from 5100 in 2015 to 9600 euro in 2040. Demography, prosperity, and technology are the main driving forces behind growth in health care expenditures. The aging population in the Netherlands results in higher expenditures, because elderly need more care than youth (1). This could be addressed by increasing health care funding, however this requires taking money away from other areas which is only acceptable up to a certain point (2). As a result, the healthcare system is challenged by a need to rationalize resources and to improve efficiency as well as effectiveness within the healthcare sector (3).

At this moment, many interventions can be afforded. However, many interventions are not valuable. This means that comparable interventions exist that are more cost-effective (2). In healthcare many inefficiencies exist. Inefficiency in healthcare is defined as: “a wasteful use of resources for no or very little benefit or a failure to use resources on clearly beneficial activities.” Inefficiency has a huge impact on costs and quality of care (4). It has been agreed in the Outline Agreement Medical Specialist Care 2019-2022 to promote appropriate use of specialist medical care (5). Quality improvements and implementation strategies need to change the behavior of individuals or organizations in response to healthcare efficiencies (4).

In the healthcare sector conflicting targets, values, and drivers exist. The principal goal for medical specialists is to look carefully at what sensible care is for patients (3). This can be done by looking at the value of patient care. Porters Value Based Healthcare (VBHC) is a popular method for maximizing the value of patient care (6). Value of patient care is defined as the value of patient relevant health outcomes in relation to the costs (7). By focusing on outcomes, VBHC delivers improved care to patients, makes optimal use of finite resources, and helps to manage cost increases. At this moment providers are paid based on the amount of healthcare services they deliver, but it should be based on the value that they deliver. This requires a shift in healthcare: from supply-driven to patient-driven (8).

1.2 Value in healthcare

Many definitions of value in healthcare exist. Value can be considered from governmental, public, clinician, insurer and patient perspective (2). The most simple definition of value is outcomes divided by costs (9). However, in this study the patient's value is important. Therefore, value is defined as health outcomes achieved which matter to patients, per euro spent to achieve those outcomes (10). Porter argues that value should always be defined around the patients. Outcomes of interest to the patients include both quality of care and the experience for the patients and families when receiving care. If two medical conditions provide the same outcomes, the less-expensive one provides greater value (11).

However, effectiveness, cost-effectiveness and quality are all important in healthcare. It is possible for an intervention to be all the above but still have limited value for an individual patient. Interventions that do not add value from the patient's perspective can be considered as overuse and this results in unnecessary costs and risks. Underuse also reduces value because patients do not receive care that adds value for the patient. A focus on the highest value for patients can support optimal use of limited resources and avoid waste through overuse and low-value interventions (2). Some studies suggest that value-based healthcare interventions could revolutionize the healthcare system and tackle some key challenges faced across the globe, while other suggest that benefits are more likely to be incremental, with small changes and improvements over time (12).

1.3 Company X' value-oriented care purchasing process

Company X is the fourth largest health insurance company in the Netherlands located in Groningen, Wageningen and Enschede (13). Around 2.2 million people are currently insured with Company X (14). Company X' vision is to work from their passion and commitment to healthcare. Therefore, Company X has developed a value-orientated care purchasing process, based on principles of VBHC (15). This intervention is aimed at small changes and improvements over time can be considered as an incremental. The value-oriented care purchasing process is a three-year process, that can be used for many conditions (15). In this study, the focus is on hip and knee replacements. The first outcomes are available right now, because Company X' value-oriented care purchasing process for knee and hip replacements has been going on for two years now.

The main goal of this process is to maximize value of patient care, increase quality of care and reduce healthcare costs. This is done based on improvement cycles: (1) Collect data and benchmark with peers; (2) Examine differences and identify improvements; (3) Implement improvements. This is the core of the value-oriented care purchasing process (16).

Participants of the value-oriented care purchasing process participate in an annual mirror meeting where outcomes are presented and discussed. At this moment 22 hospitals / institutions are participating for knee arthritis and 20 hospitals / institutions are participating for hip arthritis. Relevant indicators prepared by The International Consortium for Health Outcomes Measurement (ICHOM) are used as health outcomes measurement. Company X wants to connect as much as possible with the standard set of indicators developed by ICHOM for hip and knee osteoarthritis. Examples of quality indicators are revisions within one year and PROM differences scores. Company X will not label the quality of the healthcare providers. So, Company X does not say whether care is "good" or "bad", but differences between healthcare providers will be made transparent (16).

For costs, there is looked at cost drivers. These are the parts of the care that are responsible for most of the costs of treatment. This does result in an incomplete display of costs, but measuring complete costs is difficult and time-consuming for providers. Examples of cost-drivers that are measured are nursing days and number of X-rays. The participants receive benchmark data of the outcomes and cost drivers benchmarked by an independent party (i2i). Participants participate in annual mirror meetings in which the benchmark data is presented and discussed. The goal of these meetings is that participants are inspired by other participants and increasing the value of care by creating an environment of continuous improvement. Every participant is obliged to develop an improvement plan about decreasing the number of hospital days, decreasing the number of imaging activities, cooperation between the first and second line of care, shared decision making and after care. Company X evaluates the improvement plans on the presence of an improvement team, concrete improvement points and a time schedule for the implementation and monitoring of the improvements (16).

By sharing the results of this purchasing process with its customers, Company X wants to help its customers with the choice of a healthcare provider for a treatment. When this results in more customers for healthcare providers that offer better quality, this should not be hampered by volume agreements between the healthcare provider and Company X. Therefore, volume growth of hip and knee arthroplasty are approved, only when the quality of care is improved. It is not intended that this free volume leads to a widening of indicator assessment, which results in more surgeries. In 2018 Company X has started making episode-based payment for hip and knee prostheses, including diagnostics, surgery, outpatient visits and complications. This is the first step in the principle of bundled payment. Bundled payment is a reimbursement method of healthcare providers based on expected costs for a condition for an episode of care. In the coming years, the bundle will be expanded with parts of the aftercare, namely geriatric rehabilitation and physiotherapy (16).

1.4 Problem formulation

In the literature, value-added programs are often mentioned to improve the quality of care and reduce healthcare costs. Healthcare systems are rapidly moving toward rewarding value. However, there exists less evidence of actual cost savings and quality improvement after the introduction of value-added programs. The challenge of determining effectiveness of value-oriented programs is not only complicated by how one might define success, but also by external factors (17). Lee et al. (2016) found that the implementation of a value-driven outcomes tool that allocates clinical care costs and quality measures to individual patients encounters was associated with improvements in value of care: reduced costs and improved quality for three selected clinical projects (18). Gabriel et al. investigated if pathway redesign based on the principles of VBHC could increase value. This was done by comparing two care pathways on outcomes that matter to patients as well as the costs of delivering them. No significant clinical outcomes were identified, but the value was increased due to lower pathway costs (19).

Therefore, this study will try to address if the value-oriented care purchasing process for knee and hip arthroplasty developed at Company X contributes to a higher value of care.

1.5 Objective and research question

Having presented the problem, the research objective of this study is defined as to identify whether the value-oriented care purchasing process for total joint arthroplasty contributes to a higher value of care in comparison to general care (standard, not value-oriented care). Total joint arthroplasty is suitable because these are elective procedures and there is a wide variation in treatment approaches. In total joint arthroplasty there is enough information about the care pathway and there are clearly defined metrics of value in terms of costs and outcomes. Because of the different treatment approaches it is possible to shape and evaluate improvements to increase the value for the patients (20). Before the research question can be answered, first there needs to be determined which characteristics possibly have an influence on the clinical outcomes for patients with total joint arthroplasty. The outcome of this study can inform decisions on whether the value-oriented care program process should also be tested or used for other diseases. To investigate the objective, the research question is formulated:

"To what extent does Company X' Value-oriented care purchasing process for total joint arthroplasty result in better outcomes?"

The research question will be answered with the following sub questions:

1. Which outcome and cost measures are relevant to determine the effect of the value-oriented care program for total joint arthroplasty?
2. Which variables (control variables) can have an influence on the outcome and cost measures for total joint arthroplasty?
3. What is the contribution of the value-oriented care purchasing process on outcome and cost measures for total joint arthroplasty?
4. Should the value-oriented care purchasing process be disseminated to other diseases?

1.6 Reading guide

The introduction has presented the problem and research questions of this study. In chapter two, relevant outcome measures will be identified based on relevant literature. After that, control variables are identified. In chapter three, the methods of the analysis are explained. In chapter four, the results of the analysis are shown. In chapter five, the discussion and advise of this study is presented. There will also be discussed whether the value-oriented care purchasing process should be disseminated to other diseases.

2. Mini-literature review determining measures / variables

In this chapter, first the methods to identify relevant outcome and cost measures for value in total joint arthroplasty will be described. After that, results of the mini literature review will be presented. Lastly, methods and results for control variables that could influence outcomes and cost measures of total joint arthroplasty will be described.

2.1 Relevant outcome measures for value in total joint arthroplasty

2.1.1 Methods determining relevant outcome measures.

Value is generally defined as outcome divided by cost. It is difficult how to define and measure value. Therefore, the first step was defining relevant outcome measures to measure value in healthcare for total joint arthroplasty. This was done based on a mini-literature review in three steps. The first step was finding relevant studies in Scopus, Google scholar and Pubmed. Search terms were related to: “total joint arthroplasty”, “hip and knee joint replacement”, “Value-based healthcare” and “bundled payments”. All search terms can be found in appendix 1. Articles published after year 2010 have been included in the literature review. Articles were excluded when VBHC or aspects of VBHC were not considered. For judging when to stop reviewing, theoretical saturation was used. This means that there was stopped reviewing, when no additional outcome and cost measures were found after reviewing a great number of other studies (21). Step two consists of counting the outcomes and selecting the most used outcome and cost measures of comparable studies. Outcome and cost measures that were mentioned less than two times have been disregarded. In this way a list with relevant quality and cost measures was created. Step three consisted of examining which of the relevant quality and cost outcome measures could be derived from Company X and Vektis data sources.

2.1.2 Step one: Results mini literature review

In this study value is defined as health outcomes achieved which matter to patients per euro spent to achieve those outcomes. Therefore, relevant outcome measures are divided into outcomes and costs. Because no single outcome captures the results of care, multiple measures will be used to measure the outcomes of care. Relevant outcome measures for knee and hip arthritis are determined by the International Consortium for Health Outcomes Measurement (ICHOM). They have developed a standard set with the aim of measuring outcomes that matter most to patients across the full cycle of care. (22). The following outcome measures are covered within the standard set: Hip or knee functional status (HOOS-PS or KOOS-PS), pain in the hips, knees or lower back (VAS), quality of life (EQ-5D-3L or SF-12), work status, satisfaction with results, death, admissions and reoperations (22). ICHOM has not developed a standard set for cost measuring, because it is difficult to compare the total costs. Therefore, it is recommended to look at the cost drivers of the provided care. These cost drivers are responsible for the biggest part of treatment costs. Relevant cost drivers according to Company X are number of hospital days, number of outpatient clinic visits, number of X-rays, number of MRI's, number of intramural physiotherapy treatments, first-line stay days, number of hours district nursing and extramural physiotherapy. These cost drivers are developed in cooperation with medical specialists (16). Relevant measurers that are used in comparable studies are shown below, in table 1 a summary of these measures is given.

Lee et al. (2016) performed an observational study measuring the clinical outcomes of a value-driven outcomes tool for hip and knee joint replacement. Outcomes that were used in this study were: risk-adjusted mortality, hospital-acquired infections, 30-day hospital readmissions, emergency department visits within 90 days of discharge, and early mobility out of bed on day of surgery. Another important measure that was used in this study were PROMs. Costs measurers that were used in this study are healthcare professional costs, hospital days, outpatient visits, and laboratory testing (18).

A study of Dundon et al. (2016) investigated possible improvements in total joint replacement quality metrics after the introduction of a patient-centered approach with increased care coordination and supported with bundled payments. Outcome measures that were used in this study were: Length of stay, readmissions, discharge disposition and cost per episode of care (23).

Navathe et al. (2017) identified cost drivers in bundled payment for joint replacement surgeries. Main outcomes and measures were average medicare payments per episode including: professional fees, durable medical equipment, outpatient visits, emergency department visits, readmission, skilled nursing facilities, inpatient rehabilitation facilities, home health agencies, long term acute care providers and time-driven activity-based costing. outcome measures used in this study were 30-day readmission, ER visit rates and Length of stay (24).

An international working group of patients, orthopedic surgeons' physicians and many others have defined a minimum standard set of outcome measurers for monitoring, comparing, and improving health care for patients with hip or knee osteoarthritis. The outcomes included in the Standard Set were: Patient reported health status (HOOS-PS), pain (VAS), Quality of life (EQ-

5D-3L), work status, 30-day mortality, 30-day readmissions, reoperations and disease progression (25).

Santeon (seven Dutch top clinical hospitals) is working together to improve hip osteoarthritis care based on the principles of VBHC. They compare results and learn from each other. They have divided the measurement in three parts: outcome, costs, and process. Outcome measurers are: PROMs, complications during admission to primary hip surgery, Complications after primary hip surgery (during and within 30/90 days after admission) and reoperations within 2 years. Cost measurements that were used were: net operating time per patient, average purchase price per hip, length of stay inclusive readmissions, admission on the day of surgery and Diagnostic activities per patient (26).

Another study of Gabriel et al. (2019) investigated if pathway redesign based on the principles of VBHC could increase value of treatment for primary hip osteoarthritis through measuring outcomes that matter to patients as well the costs. Outcomes that were used in this study were: PROMs which compromise OHS, EQ-5D-5L and EQ-VAS. To establish baseline costs, each care pathway was mapped in detail. Each part of the pathway was allocated a cost. The total cost per patient was established using the patient level information costing system methodology (19).

Featherall et al. (2019) performed a study about total knee arthroplasty care pathways. Care pathways are considered as the first step towards the shift toward value-based and are considered as increasingly important. Outcomes that were used in this study were: episodes of care cost, length of stay, discharge disposition, 90-day complications, and patient experience (HCAHPS) (27).

Johnson et al. (2019) aimed to determine whether participation in bundled payment for total joint arthroplasty negatively affects patients' functional recovery. Patients were categorized into pre-bundle and post-bundle cohorts. Mixed-effects linear regression and Wald post-tests were used to find differences in Length of stay, functional recovery self-tests and PAC facility use (discharge location) (28).

Study	Measurers
Outcomes	
ICHOM	Hip or knee functional status (HOOS-PS or KOOS-PS), pain in the hips, knees or lower back (VAS), quality of life (EQ-5D-3L or SF-

	12), work status, satisfaction with results, death, admissions and reoperations.
Lee et al. (2016)	Risk-adjusted mortality, hospital-acquired infections, 30-day unplanned hospital readmissions, emergency department visits within 90 days, early mobility, and PROMs.
Dundon et al. (2016)	Readmissions, discharge disposition
Rolfsen et al. (2016)	Patient reported health status (HOOS-PS), pain (VAS), Quality of life (EQ-5D-3L), work status, 30-day mortality, 30-day readmissions, reoperations, and disease progression.
Navathe et al. (2017)	Readmissions, emergency department visits, Length of stay
Santeon (2018)	PROMs, complications during admission to primary hip surgery, Complications after primary hip surgery (during and within 30/90 days after admission) and reoperations within 2 years.
Gabriel et al. (2019)	Survival and PROMs which compromise OHS, EQ-5D-5L and EQ-VAS
Featherall (2019)	Discharge disposition, 90-day complications, and patient experience (HCAHPS)
Johnson et al. (2019)	Length of stay, Functional recovery self-tests and discharge location
Costs	
Lee et al. (2016)	Professional costs, hospital days, outpatient visits, laboratory testing.
Dundon et al. (2016)	Length of stay and cost per episode of care
Navathe et al. (2017)	professional fees, durable medical equipment, outpatient visits, emergency department visits, readmission, skilled nursing facilities, inpatient rehabilitation facilities, home health agencies, long term acute care providers and time-driven activity-based costing
Santeon (2018)	Net operating time per patient, average purchase price per hip, length of stay inclusive readmissions, admission on the day of surgery and Diagnostic activities per patient
Gabriel et al. (2019)	The patient level information costing system methodology.
Featherall (2019)	Length of stay and episodes of care cost.

Table 1: Summary measures per study

2.1.3 Step 2: counting outcomes and select most relevant outcomes

Relevant clinical outcome measurers for patients with total joint arthroplasty were identified in the part above. The second step was counting the outcomes that were mentioned more than twice. This resulted in the following table:

Category	Indicator	Counting
Outcome	**PROMs/ Self-evaluations/ Patient-reported**	7
	Readmissions within 30 days	5
	Mortality	4
	Revision	4
	Discharge location	3
	Complications (including infections)	3
	Emergency department visits within 90 days	2
	Length of stay	2
	Early mobility	1
	Disease progression	1
Costs	**Length of stay/ hospital days**	4
	Laboratory testing / diagnostic activities	2
	Costs per episode of care	2
	Professional costs	2
	Outpatient visits	2
	Readmissions	2
	Net operating time per patient	1
	Emergency department visits	1
	Durable medical equipment	1
	Average purchase price per hip	1
	Admission on the day of surgery	1
	The patient level information costing system methodology.	1
	Time-driven activity-based costing	1
	Inpatient rehabilitation facilities / home healthcare/ long term acute care providers	1

Table 2: Counting outcomes

2.1.4 Step 3: examining available data

The third step is identifying which variables can be derived from available data at Company X and Vektis. Within the outcome measures, PROMs and other patient reported measures are most often used as outcome measure. Unfortunately, within the available dataset of Company X, PROMs and other patient reported measures are only available on hospital level instead of patient level. Therefore, PROMs will not be used in this study. Mortality is not included because mortality is very low in knee and hip arthroplasty in the Netherlands. In this way, the analysis will be sensitive for fluctuations and will therefore be left out (29). Discharge locations after leaving the hospital are also not available within Company X' declaration data. Within the dataset of Company X it is difficult to combine relevant complications to knee and hip arthroplasty, therefore there is chosen to use infections based on prescribed antibiotics within 30 days.

Relevant cost measures that will be neglected in this study are costs per episode of care and professional costs. Costs per episode of care costing is not used within orthopedic surgery in the Netherlands (30) and professional costs could not be derived from Company X' declaration data. Outcome measures that are used in this study are shown in table 3.

Category	Indicator	Explanation
Outcome	Readmissions	Within 30 days
	Revision	Continuous
	Infections	Within 30 days
Costs	Length of stay	Days
	Imaging	Number of x-rays and MRIs
	Outpatient visits	Number of visits
	Readmissions	Within 30 days

Table 3: Outcome measures

2.2 Variables (control variables) that could influence outcomes of total joint arthroplasty

2.2.1 Methods identifying relevant control variables

For identifying variables that could possibly influence outcome and cost measures for total joint arthroplasty a mini-literature review in two steps was performed. These variables are only used as control variables in the analysis. The only predictor of interest is value-oriented care purchasing process. However, control variables must be included to interpret the analysis. The first step was searching in Scopus, Google scholar and Pubmed. Search terms were broader in comparison with the first mini-literature review, because all variables that have an influence on the outcomes of total joint arthroplasty could be considered. Therefore, search terms used in this mini-literature review were related to: “total joint arthroplasty”, “hip and knee joint replacement”, “readmission”, “revision”, “complications”, “mortality”, “imaging”, “length of stay”, “outpatient visits” and “regression”. All search terms can be found in appendix 1. Articles published after year 2010 have been included in the literature review. For judging when to stop reviewing, theoretical saturation was used. Step two consisted of examining which variables could be derived from Company X. The selection based on counting has been omitted, because all variables that could possibly affect quality and cost outcomes and are available at Company X will be considered. In this way there will be tried to keep the validity as high as possible.

2.2.2 Step one: Results mini literature review

Namba et al. (2013) examined risk factors that were associated with deep surgical site infections after primary total knee arthroplasty. This was examined using cox regressions models. Patient demographics and characteristics that were used were: gender, race, diabetes, BMI, American Society of Anesthesiologists Classification score, Diagnosis, age and time to infection (31).

A study by Voskuijl et al. (2013) investigated whether an increased Charlson Comorbidity Index was associated with readmission, an increased risk of surgical site infection or other adverse events, transfusion risk or mortality after orthopedic surgery. Ordinary least squares regression analyses were used to determine whether the CCI was associated with these outcomes. Variables that were used in the study were the surgeon, patient’s age, sex, race, marital status, timing of the operation, duration, length of hospital stay, and orthopedic subspecialty performing surgery (32).

Stambough et al. (2015) investigate the impact of incremental perioperative practice changes and the adoption of rapid recovery protocols in hospital length of stay and readmission rates that is associated with total hip arthroplasty. The association between surgical era and the primary outcomes length of stay and readmissions was assessed with Poisson and logistic regression. Demographic variables that were used in this study are: year, gender, number of surgeries performed, race, anesthesia type, osteoarthritis, avascular necrosis, American Society of Anesthesiologist Classification score and discharge status (33).

Gold et al. (2016) studied the association of depression with 90-day hospital readmission after total joint arthroplasty. Retrospective cohort data were analyzed using multivariable logistic regression to predict odds of 90-days readmission for total knee arthroplasty or total hip arthroplasty. In this study there is controlled for age, sex, race/ethnicity, Medicaid insurance, comorbidities and admission year (34).

Nichols et al. (2016) evaluated the factors and costs that were associated with discharge destination and readmissions for total joint arthroplasty. Logistic regression was used to analyze factors. Demographic and clinical characteristics that were used in this study were: Age, gender, residence (district), Charlson score, top Charlson comorbidities (diabetes, chronic pulmonary disease, rheumatologic disease, renal disease, congestive heart failure and obese (35).

A study of Williams et al. (2017) identified the association between hospital length of stay and 90-day readmission risk within a total joint arthroplasty bundled payment initiative. This was done by analyzing the medical records of lower extremity total joint patients enrolled in centers for Medicare and Medicaid services' bundled program for care improvement using binary logistic regression. Demographic variables consisting of age, sex, race, ethnicity, body mass index, American society of anesthesiologist score and discharge location were examined in this study (36).

Ross et al. (2019) evaluated trends and predictors of thirty-day readmissions and emergency department visits after total knee arthroplasty. This was done using multivariate logistic regression modeling. Predictors of thirty day readmission were older age, male, lower income, not having a postoperative visit with a primary care physician, increased comorbidities, longer length of stay, urgent or revision surgery, admission to a teaching hospital and discharge to an inpatient rehabilitation facility (37).

Study	**Control variables**
Voskuijl et al. (2013)	the surgeon, patient's age, sex, race, marital status, timing of the operation, duration, length of hospital stays, and orthopedic subspecialty performing surgery
Namba et al. (2013)	Gender, race, diabetes, BMI, ASA score, Diagnosis, age, and time to infection
Stambough et al. (2015)	year, gender, number of surgeries performed, race, anesthesia type, osteoarthritis, avascular necrosis, American Society of Anesthesiologist and discharge status (33).

Gold et al. (2016)	age, sex, race/ethnicity, Medicaid insurance, comorbidities, and admission year
Nichols et al. (2016)	Age, gender, residence (district), charlson score, top charlson comorbidities (diabetes, chronic pulmonary disease, rheumatologic disease, renal disease, congestive heart failure and obese
Williams et al. (2017)	age, sex, race, ethnicity, body mass index, American society of anesthesiologist score and discharge location
Ross et al. (2019)	Age, sex, income, postoperative visit primary care physician, comorbidities, length of stay, revision surgery, teaching hospital and discharge location.

Table 4: Control variables per study

2.2.3 Step 2: examining available data at Company X.

Control variables that could influence quality and outcome measures can be divided in three different levels: patient, surgeon and organizational related. Patient related variables that are relevant according to comparable studies and are available within Company X' database are: age, gender, comorbidities and length of stay. There is no information available at the patient level regarding BMI, race, ethnicity, and discharge location. The Medicaid insurance is not relevant, because all patients are insured at Company X. Relevant comorbidities are selected based on counting of relevant studies (38-43). Cardiovascular diseases, diabetes mellitus, rheumatism, COPD and Asthma are taken into consideration. The decision table of relevant comorbidities is shown in appendix 1.

Surgeon related characteristics are also considered relevant according to other studies. However, within the available data only the name of the orthopedic surgeon can be identified. This is not relevant, because there are too many different orthopedics performing the surgeries to include in the regression model. The number of surgeries performed is important. Therefore, the number of surgeries performed within the organization will be included. Anesthesia type, postoperative visit of a primary care physician, timing and duration of the operation cannot be derived from the data.

One organizational related characteristic is considered: whether the hospital/clinic is a teaching hospital. This because teaching hospitals could possibly treat more severe patients in comparison with normal or top clinical hospitals.

Level	**Control variables**
Patient	Age
	Gender
	Comorbidities
	Length of stay
Surgeon	Number surgeries performed
Organizational	Teaching hospital
	Number surgeries performed

Table 5: Control variables included in this study

3. Methods

In this chapter, first the measures that will be used in this study will be specified. After that, the data collection process and statistical analysis will be discussed. This study contains a quantitative, testing, and cross-sectional study method.

3.1 Measures

Outcome and cost measures that were used in this study were identified in the mini literature review. Readmissions, revisions, and infections were used as binary variables: 0 was no readmission, revision, or infection and 1 was expressed as the presence of a readmission, revision, or infection. The first cost measure used in this study was hospital stay. This was used as a binary variable because two different declaration codes exist: 0 means five or less hospital days, 1 means more than five hospital days. The second cost measure used in this study was imaging. Imaging includes MRI hip and lower extremities, X-ray of the knee and / or lower leg and X-ray of pelvis and hip. Imaging was used as binary variable and the cut-off value was identified based on equal classes. Imaging activities were divided into two categories: 0-2 imaging activities and 3 or more imaging activities. Outpatient visits were also used as a binary outcome measure. Outpatient visits that were included were: call consultations, first outpatient visits, repeat consultations, clinical peer consultation and co-treatment. Outpatient visits were divided into two levels: 0-3 outpatient visits and 4 or more outpatient visits. In table 6 a summary of the outcome and costs measures are shown. In comparable studies, readmissions are included both as outcome and cost measure.

Category	Indicator	Explanation	Measurement level
Outcome	Readmissions	Within 30 days	Binary (yes, no)
	Revision	Continuous	Binary (yes, no)
	Infections	within 30 days	Binary (yes, no)
Costs	Length of stay	Days	Binary (0-5 and > 5)
	Imaging	Number of x-rays and MRIs	Binary (0-2 and > 2)
	Outpatient visits	Number of visits	Binary (0-3 and > 3)
	Readmissions	Within 30 days	Binary (yes, no)

Table 6: Outcome and cost measures specified

The goal of this study was identifying the effect of value-oriented care purchasing on relevant outcomes. Therefore, the effect of the independent variable on the outcome and cost measures was identified. In this study the independent variable was whether the hospital was participant/non-participant of the value-oriented care purchasing process of Company X. All patients were categorized as participant/ non-participant based on the hospital that they were treated in. Control variables used in this study were: age, gender, comorbidities (Cardiovascular diseases, diabetes mellitus, rheumatism, COPD/Asthma), length of stay and teaching hospitals. Number of surgeries performed in a hospital and mean number of surgeries per orthopedist were used as scale variables.

3.2 Data collection

In total, 3858 hip arthroplasty patients and 3866 knee arthroplasty patients were included. Data were retrospectively collected. Care pathways that were included were diagnosis codes 1701 (Arthrosis pelvis / hip / thigh) and 1801 (Arthrosis knee). Health product codes that were included were: 131999052 (Insertion of a hip prosthesis during hospitalization), 131999051 (Insertion of a hip prosthesis), 131999104 (insertion of a knee prosthesis during hospitalization) and 131999103 (insertion of a knee prosthesis). Patients were included when the DBC was opened in 2018. Patients were removed when more than one orthopedic surgery was performed in 2018 (for example, a knee and hip arthroplasty) otherwise, care activities could not be matched with the right surgery.

Information regarding outcomes and costs were collected from declaration data of Company X. Readmissions could not directly be tracked. Therefore, this was done by identifying intermediate positions within series of hospital days. When a hospital day does not follow up the previous day, this indicates a readmission. After this, readmissions within thirty days were counted. Revisions should be measured life-long after knee or hip arthroplasty. At this moment, data of 2020 was not available. Therefore, revisions before 2020 were included. The factual number of revisions will be higher. Infections were identified based on antibiotics prescribed within 30 days after surgery. It is expected that the number of prescribed antibiotics for infections is lower than the actual number because antibiotics could also have been prescribed for other diseases. However, the largest part prescribed antibiotics is due to infections after surgery and this higher number prescribed antibiotics accounts for all hospitals.

3.2.1 Patient level characteristics

Data about patient level characteristics were derived from Company X' database. Patient level characteristics that were included were: age, gender, comorbidities, hospital days and readmissions. Age was used as a scale variable. Gender was included as a nominal variable. Comorbidities codes that should be included were defined in dialogue with advisory physicians. Cardiovascular diseases, Diabetes mellitus, respiratory diseases and rheumatoid arthritis were included as nominal variables. Hospital days were included as scale variable and readmissions as a nominal variable.

3.2.2 Hospital level characteristics

Patients treated in the same hospital could be more similar than patient treated in different hospitals. 85 hospitals were included in this study. Each hospital has been assigned a hospital number. To distinguish potential effects of hospital level characteristics, hospitals were divided into teaching and nonteaching hospitals. Also, number of knee and hip arthroplasty surgeries per year were included and mean number of surgeries per orthopedic per year were included as scale variables. Information about the number of surgeries performed and mean number of surgeries performed per orthopedic were obtained from Vektis Intelligence. Information regarding whether the hospital was participant or non-participant of the value-oriented care purchasing process was derived from Company X. The value-oriented care purchasing process is a dichotomous independent variable that can vary between 0 (no participant) and 1 (participant). In 2018, 19 hospitals/clinics were participant of the value-oriented care purchasing process. 50,5% of patients with hip and knee arthroplasty were treated in a participating hospital/clinic. In figure 1 patient and hospital variables are displayed.

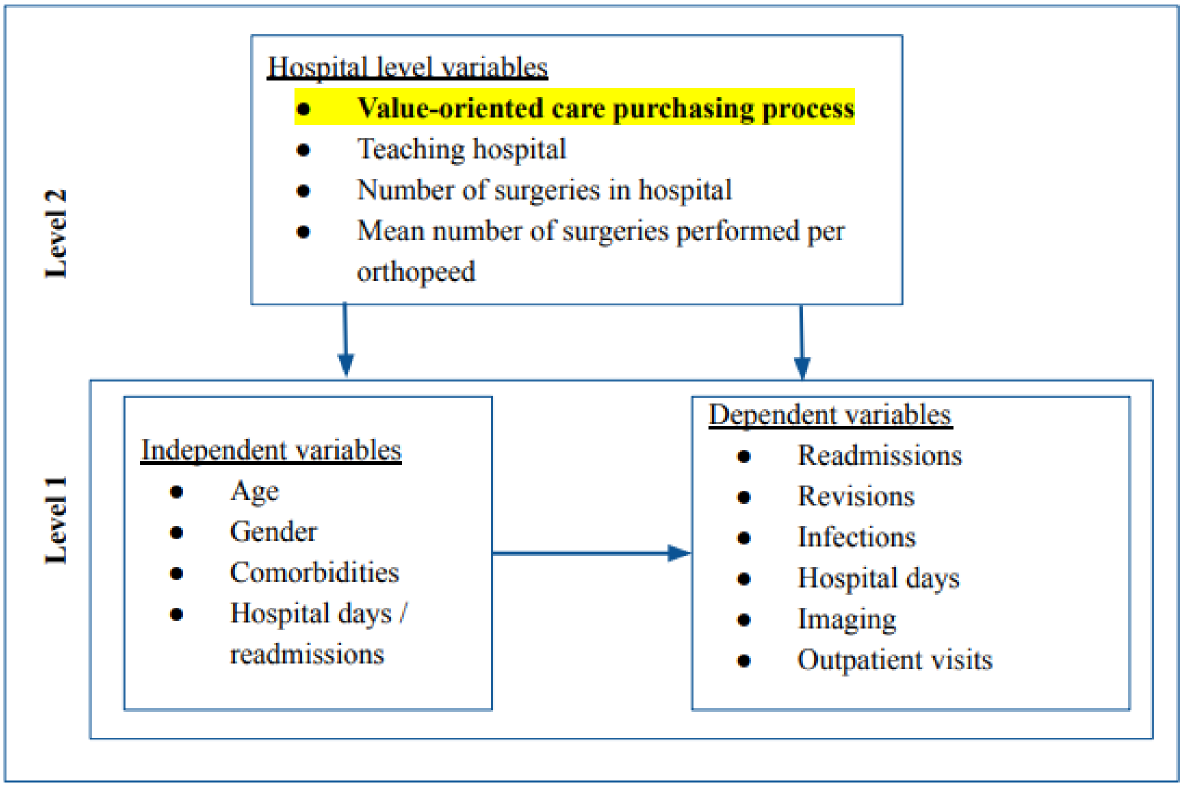

Figure 1: Research model

3.3 Statistical analysis

Baseline characteristics of patients were summarized with frequencies and percentages for categorical variables and as mean and standard deviation for continuous variables. First, a binary logistic regression was performed for all outcome and cost measures. However, the assumption of independence of observations may not hold because of the hierarchical structure of the data (data on patient and on hospital level). Therefore, different multilevel regression models were developed to test the effect of value-oriented care purchasing on several outcome and cost measures. In the multilevel analysis random effects were defined on patient and hospital level. To test a two-level binary logistic regression model, three steps were needed. The first step was calculating an empty model, with a random intercept and without exploratory variables. In this model, inter hospital variance on outcomes were analyzed. Intraclass coefficient (ICC) was calculated because this indicates the proportion of variance accounted to hospital level. If all observations were independent of one another, ICC equals 0. When observations in all clusters were exactly the same, ICC equals 1 (44). An ICC of 10% or higher calls for using multilevel analysis (45). However, it has been argued that an ICC of 1% may also have design effects that should not be ignored (46). The formula to calculate ICC is shown below. In which $\Pi^2/3$ denotes the variance of a logistic distribution.

$$\text{ICC} = \frac{\text{var}(u_{0j})}{\text{var}(u_{0j}) + \left(\pi^2 / 3\right)}$$

When ICC was redundant (<0,001%), results of the binary logistic regression were interpreted. Otherwise, the level 1 model was developed. In this model patient level characteristics: age, gender, comorbidities, hospital days and or readmissions were included. After that, the level 1 model was expanded with hospital level characteristics: value-oriented care purchasing process, teaching hospital, number of surgeries performed and mean number of surgeries per orthopedic. In this way the level 2 model was created. In figure 2 the different steps are summarized.

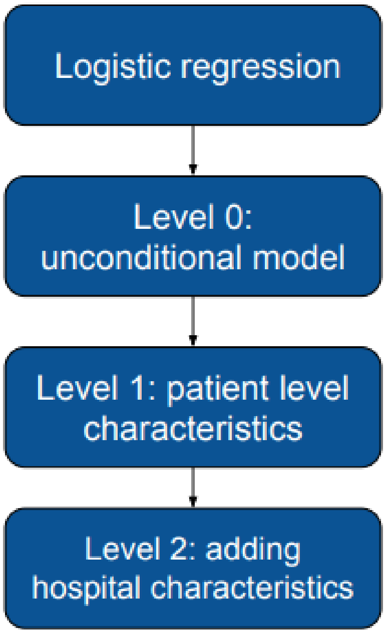

Figure 2: Summary steps statistical analysis

With the regression models the influence of the value-oriented care purchasing process on the selected outcomes and costs were determined. P values ≤ .05 were considered statistically significant. For these analyses, SPSS statistical software version 26 was used (47).

4. Results analysis

This chapter starts with an overview of patient characteristics. After that, results of logistic regression and multilevel analysis are shown for readmissions, revisions, infections, hospital days, imaging, and outpatient visits.

4.1 Overview patients

In total, 1898 patients with knee arthroplasty were treated in a participating value-oriented care purchasing hospital (VOP), and 1968 patients were treated in a non-participating hospital (non-VOP). For knee arthroplasty, most patients were female, and the mean age for VOP was 67,7 and for non-VOP 67,5. Patients treated in a participating hospital had a higher rate of Diabetes mellitus and respiratory diseases but a lower rate of arthritis patients. Readmissions were quite comparable for participating and non-participating hospitals, but the mean hospital days and outpatient visits significantly vary between VOP and non-VOP hospitals. For hip arthroplasty, 1935 patients were treated in a participating hospital and 1923 patients in a non-participating hospital. For hip arthroplasty, the mean age for patients treated in a VOP hospital was 68,9 and for non-VOP hospitals 68,8. Non-participating hospitals had a higher rate of male patients and a lower rate of Diabetes mellitus. The mean number hospital days, imaging activities and outpatient visits were significantly varying. In table 7, general characteristics are exhibited. In figure 3 and 4 patient distribution per hospital is exhibited.

Characteristics 2018	Knee		Hip	
	VOP N=1898	Non-VOP N=1968	VOP N=1935	Non-VOP N=1923
Male	700 (36,9%)	733 (37,2%)	611 (31,6%)	687 (35,3%)
Age mean	67,7 (9,1)	67,5 (8,9)	68,9 (10,7)	68,8 (10,1)
Heart diseases	238 (12,5%)	245 (12,4%)	244 (12,6%)	253 (13,2%)
Diabetes mellitus	65 (3,4%)	32 (1,6%)	61 (3,2%)	16 (0,8%)
Respiratory	67 (3,5%)	52 (2,6%)	62 (3,2%)	51 (2,7%)
Arthritis	28 (1,5%)	53 (2,7%)	35 (1,8%)	32 (1,7%)
Readmissions	34 (1,8%)	32 (1,6%)	40 (2,1%)	41 (2,1%)
Revisions	38 (2,0%)	41 (2,1%)	47 (2,4%)	35 (1,8%)
Infections	54 (2,8%)	55 (2,8%)	58 (3,0%)	42 (2,2%)
Hospital days mean	3,55 (2,0)	3,70 (1,9)	3,38 (2,7)	3,62 (2,3)
Hospital <5 days	1777 (93,6%)	1646 (83,6%)	1753 (90,5%)	1676 (87,2%)

Imaging mean	2,20 (1,2)	2,15 (1,3)	2,82 (1,5)	2,53 (1,5)
Outpatient visits mean	3,71 (2,2)	4,23 (2,4)	3,33 (2,1)	3,56 (2,0)

VOP = value-oriented care purchasing

Table 7: Overview patients

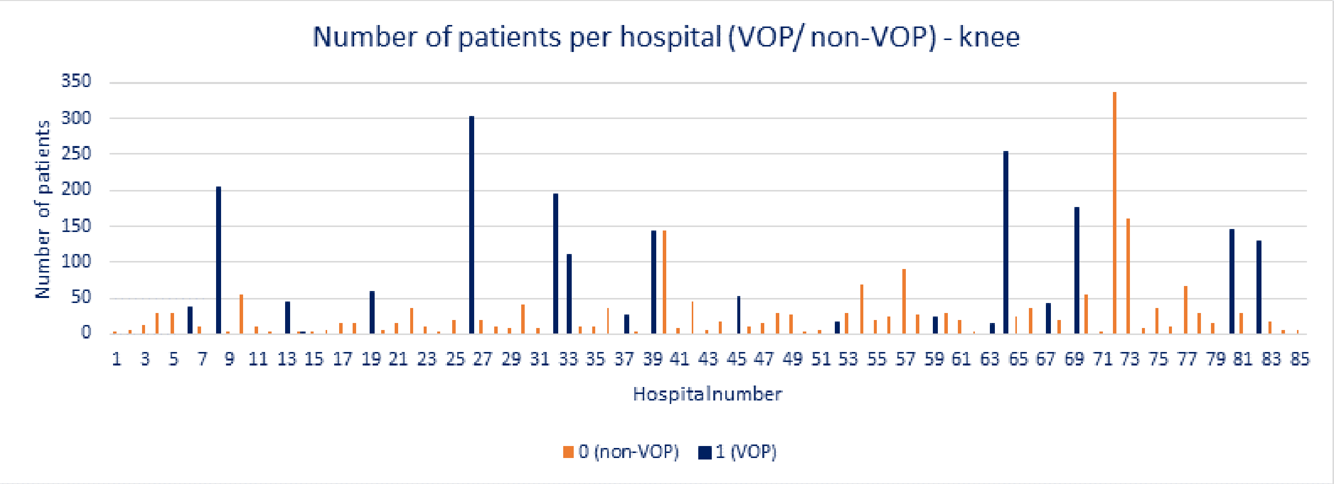

Figure 3: Distribution number of patients per hospital - knee

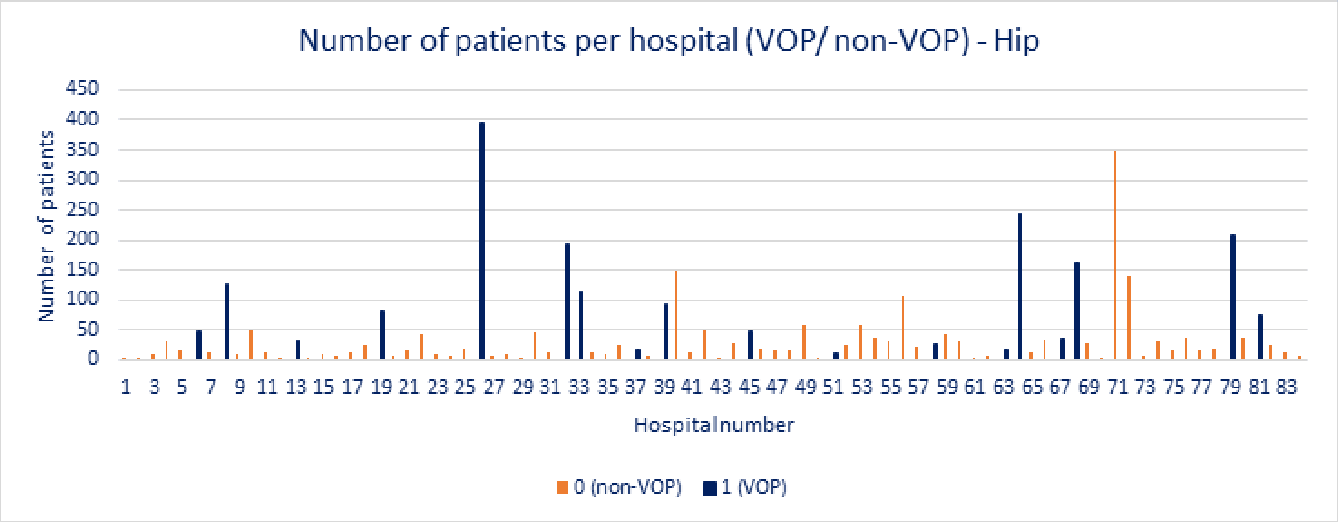

Figure 4: Distribution number of patients per hospital - hip

4.2 Readmissions

1,8% of patients treated in a participating hospital had a readmission after knee arthroplasty and 1,6% of patients had a readmission treated in a non-participating hospital. Logistic regression was performed to determine the effect of participating in a value-oriented purchasing process on the likelihood that patients have had readmissions within 30 days after knee and hip arthroplasty. Step two was performing multilevel analysis. For both, knee, and hip arthroplasty the hospital number variance was redundant; ICC was below 0,001%. Therefore, multilevel analysis was not relevant, the results of logistic regression could be interpreted. In appendix 2, the output of the unconditional model is shown. For knee arthroplasty, the model explained 19,7% (Nagelkerke R^2) of the variance in readmissions. VOP results in a non-significant increase on the likelihood of a readmission. The chance of a readmission increases with 27,4% for patients treated in a VOP hospital.

For hip arthroplasty, 2,1% of patients had a readmission both in participating and non-participating hospitals. The logistic regression model explained 24,7% of the variance in readmissions. VOP results in a non-significant increasing effect on the chance of readmissions. The chance of a readmission increases with 10,3% for patients treated in a VOP hospital. However, in the general characteristics is shown that the readmission rate is equal in both VOP and non VOP hospitals. In the regression analysis, control variables are included. On average, hip arthroplasty patients treated in a non-VOP hospital had a longer hospital stay compared with patients treated in a VOP hospital. Hospital days significantly increase the chance of a readmission.

Predictor variables	**Knee**		**Hip**	
	Standardized β coef.	Exp(B)	Standardized β coef.	Exp(B)
Age	-,016	,984	-,008	,992
Gender	-,486	,615	-,247	,781
Hospital days	,402***	1,496	,293***	1,341
Cardiovascular diseases	,045	,956	,744*	2,105
Diabetes mellites	,745	2,107	,627	1,872
Respiratory	-,362	,696	,186	1,204
Rheumatoid arthritis	-1,336	,263	,724	2,062
VOP	**,242**	**1,274**	**-,098**	**1,103**
Teaching hospital	-18,169	,000	-,343	,710

Surgery numbers	,000	1,000	-,001	,999
Mean orthopedic	,000	1,00	,003	1,003
Constant	-4,972***	,007	-4,757***	0,009

*P<0.05, **P<0.01, ***P<0.001.

Table 8: Results logistic regression readmission

4.3 Revisions

2,0% of patients treated in a participating hospital had a revision after knee arthroplasty and 2,1% of patients had a readmission treated in a non-participating hospital. First a logistic regression was performed to determine the effect of VOP on the likelihood that patients underwent revisions after knee and hip arthroplasty. After that, multilevel analysis was performed. For both knee and hip arthroplasty, the hospital variance was redundant. This resulted in an ICC below 0,001. The output of the unconditional model is shown in appendix 3. Results of logistic regression for knee arthroplasty explained 3% (Nagelkerke R^2) of the variance in revisions. VOP had a non-significant reductive effect on readmissions after knee arthroplasty. The chance of a revision decreases with 38% for patients treated in a VOP hospital.

For hip arthroplasty, 2,4% had a readmission in participating hospital against 1,8% in non-participating hospitals. The regression model explained 5,2% of the variance in readmissions. VOP had a non-significant increasing effect on the chance of revision after hip arthroplasty. The chance of a revision increases with 23,1% for patients treated in a VOP hospital.

Predictor variables	Knee		Hip	
	Standardized β coef.	Exp(B)	Standardized β coef.	Exp(B)
Age	-,024	,977	-,034**	,966
Gender	,031	1,031	,234	1,264
Hospital days	,135**	1,145	,100***	1,105
Cardiovascular diseases	-,368	,692	,259	1,295
Diabetes mellites	,740	2,095	,763	2,145
Respiratory	1,284**	3,610	,534	1,706
Rheumatoid arthritis	,445	1,560	-17,283	,000

VOP	**-,479**	**,620**	**,208**	**1,231**
Teaching hospital	-18,293	,000	-17,979	,000
Surgery numbers	,001*	1,001	,000	1,000
Mean orthopedic	-,014*	,986	-,008	,992
Constant	-2,170***	,114	-1,816*	,163

*P<0.05, **P<0.01, ***P<0.001.

Table 9: results logistic regression revisions

4.4 Infections

2,8% of patients treated in a participating hospital and 2,8% of patients treated in non-participating hospital suffered an infection after knee arthroplasty. First a logistic regression was performed to determine the effect of VOP on the likelihood that patients suffered infections after knee and hip arthroplasty. After that, multilevel analysis was performed. For both knee and hip arthroplasty, the hospital variance was redundant. This resulted in an ICC below 0,001%. Therefore, multilevel analysis was not recommended for infections. The output of the unconditional model is shown in appendix 4. Results of logistic regression for knee arthroplasty explained 5,2% (Nagelkerke R^2) of the variance in infections. VOP results in a non-significant reduction on infections after knee arthroplasty. The chance of an infection decreases with 24,4% for patients treated in a VOP hospital. However, in the general characteristics is shown that there is an equal infection rate between participating and non-participating hospitals. Respiratory diseases significantly increase the chance of infections with 243,7%. In the general characteristics is shown that within VOP hospitals, 3,5% of knee arthroplasty patients suffer respiratory diseases against 2,6% in non VOP hospitals. VOP hospitals have a higher number of patients with respiratory diseases compared to non-VOP hospitals.

For hip arthroplasty, 3,0% of patients treated in a participating hospital suffered an infection and 2,2% of patients suffered an infection treated in a non-participating hospital. The regression model explained 4,3% of the variance in infections. VOP results in a non-significant increasing effect on the chance of infections after hip arthroplasty. The chance of an infection increases with 59,4% for patients treated in a VOP hospital.

Predictor variables	Knee		Hip	
	Standardized β coef.	Exp(B)	Standardized β coef.	Exp(B)
Age	,032**	1,033	,019	1,019
Gender	-,465*	,628	-,349	,705
Hospital days	,977	1,080	,053*	1,054
Cardiovascular diseases	,688**	1,990	,447	1,563
Diabetes mellites	,409	1,505	1,196**	3,306
Respiratory	1,235***	3,437	-,219	,803
Rheumatoid arthritis	,720	2,054	,480	,619
VOP	**-,280**	**,756**	**-,466**	**1,594**
Teaching hospital	-,924	,397	-,549	,577
Surgery numbers	,000	1,000	-,002**	,998
Mean orthopedic	,000	1,000	,009*	1,009
Constant	-5,967***	,003	-5,084***	0,006

*P<0.05, **P<0.01, ***P<0.001.

Table 10: results logistic regression infections

4.5 Events (combining readmissions, revisions, infections)

Because the percentage readmissions, revisions and infections are low, the total number negative events are combined. This is done to have more events than the 1-3% per single event. 6,3% of patients treated in a participating hospital and 6,4% of patients treated in non-participating hospital suffered a negative event after knee arthroplasty. First a logistic regression was performed to determine the effect of VOP on the likelihood that patients suffered a negative event after knee and hip arthroplasty. After that, multilevel analysis was performed. For both knee and hip arthroplasty, the hospital variance was redundant. This resulted in an ICC below 0,001%. Therefore, multilevel analysis was not recommended for total events. The output of the unconditional model is shown in appendix 5. Results of logistic regression for knee arthroplasty explained 8,0% (Nagelkerke R^2) of the variance in negative events. VOP results in a non-significant reduction on negative events after knee arthroplasty. The chance of a negative event decreases with 19% for patients treated in a VOP hospital.

For hip arthroplasty, 6,9% of patients treated in a participating hospital suffered a negative vent and 5,7% of patients suffered a negative event treated in a non-participating hospital. The regression model explained 9,7% of the variance in negative events. VOP results in a non-significant increasing effect on the chance of a negative event after hip arthroplasty. The chance of a negative event increases with 30,5% for patients treated in a VOP hospital.

Predictor variables	**Knee**		**Hip**	
	Standardized β coef.	Exp(B)	Standardized β coef.	Exp(B)
Age	,000	1,000	-,012	,988
Gender	-,316*	,030	-,082	,921
Hospital days	,247***	1,281	,196***	1,217
Cardiovascular diseases	,291	1,338	,541*	1,718
Diabetes mellites	,310	1,363	1,002**	2,723
Respiratory	1,018***	2,766	,104	1,110
Rheumatoid arthritis	,353	1,423	-,225	,799
VOP	**-,210**	**,810**	**,266**	**1,305**
Teaching hospital	-2,380*	0,093	-,912	,402
Surgery numbers	,001*	1,001	-,001	,999
Mean orthopedic	-,004	,996	,001	1,001
Constant	-3,487***	,031	-2,671***	0,069

*P<0.05, **P<0.01, ***P<0.001.

Table 11: results logistic regression combined events

4.6 Length of hospital stay

Mean hospital stay after knee arthroplasty in a participating hospital was 3,55 days against a mean of 3,70 days in non-participating hospitals. Mean hospital stay after hip arthroplasty was 3,38 in participating hospitals and 3,62 in non-participating hospitals. First, a logistic regression was performed to determine the effect of VOP on length of hospital stay. For both knee and hip arthroplasty, VOP has a significant increasing effect on a hospital stay of more than five days within logistic regression. After that, a multilevel analysis was performed. ICC was 34% for knee arthroplasty and 26,5 for hip arthroplasty and therefore, there was continued to level 1 and level 2. Within the multilevel analysis, VOP has a non-significant increasing effect on a hospital stay of longer than five days after knee and hip arthroplasty. The chance of a hospital stay of more than five days increases with 37% for knee arthroplasty patients treated in a VOP hospital and increases with 52,5% for patients with hip arthroplasty despite a lower mean hospital stay for both knee and hip arthroplasty in VOP hospitals. Teaching hospitals only appear in the non VOP group. Knee arthroplasty patients treated in a teaching hospital have a 1255,5% higher chance of having more than five hospital days compared with non-VOP hospitals. Hip arthroplasty patients treated in a teaching hospital have a 2268,9% higher chance compared with non-VOP hospitals. Validity of those effects are questionable because teaching hospitals do not appear in the VOP group.

	Knee					Hip				
	Logistic r	Level 0	Level 1	Level 2	Exp(B) Level 2	Logistic r	Level 0	Level 1	Level 2	Exp(B) Level 2
Individual-level										
Age	,048***		,047***	,049***	1,050	,052***		,040***	,052***	1,053
Gender	,540***		,502***	,498***	1,645	,359*		,386**	,371**	1,449
Readmission	2,402***		1,846***	2,482***	11,960	2,866***		2,588***	2,927***	18,680
Cardiovascular	,367*		,216	,353*	1,423	,330*		,381*	,406**	1,500
DM	,268		,204	,229	1,257	,345		,110	,170	1,186
Respiratory	,286		,196	,217	1,243	,876**		,886**	,979**	2,661
RA	,086		-,088	-,003	0,997	-,147		-,154	-,261	,771
Hospital-level										
Teaching hosp.	2,938***			2,607***	13,555	3,376***			3,165***	23,689
VOP	**,560*****			**,315**	**1,370**	**,491****			**,422**	**1,525**
Surgery numbers	-,001**			-,001	,999	,000			,000	1,000
Mean orthopedic	-,007*			-,009	,991	-,004			-,005	,995
Random effect										
Hospital-var		1,308***	1,344***	,614**			1,090***	1,274***	,594**	
ICC		34%	35%	10%			26,5%	33%	9,7%	

*P<0.05, **P<0.01, ***P<0.001.

Table 12: results multilevel analysis hospital day

4.7 Imaging

Patients with knee arthroplasty were having on average 2,20 imaging activities in participating hospitals and 2,15 imaging activities in non-participating hospitals. First, a logistic regression was performed to determine the effect of VOP on the number of imaging activities. After the logistic regression, a multilevel analysis was performed. For knee arthroplasty, ICC was 3,4%, so the influence of hospital level variance was questionable. Within the level 2 model, VOP has a non-significant increasing effect on imaging activities. The chance of more than two imaging activities increases with 8,6% for knee arthroplasty patients treated in a VOP hospital.

Patients with hip arthroplasty were having on average 2,82 imaging activities in participating hospitals against 2,53 in non-participating hospitals. Within the logistic regression model for hip arthroplasty, VOP had a significant increasing effect on imaging activities. Within the multilevel analysis, ICC was 17,6% so multilevel analysis was suggested. In the level 2 model, VOP has a non-significant increasing effect on having more than two imaging activities. The chance of more than two imaging activities increases with 4,6% for hip arthroplasty patients treated in a VOP hospital.

	Knee					Hip				
	Logistic r	Level 0	Level 1	Level 2	Exp(B) Level 2	Logistic r	Level 0	Level 1	Level 2	Exp(B) Level 2
Individual-level										
Age	,011**		,009***	,009***	1,009	,020***		,015***	,016***	1,016
Gender	,113		,110*	,102	1,108	,055		,016	,028	1,028
Readmission	,817**		,488	,674*	1,290	,756*		1,025***	1,022**	2,779
Hospital days	,013		,050*	,045*	1,046	,033*		,039*	,026	1,026
Cardiovascular	-,293*		-,313**	-,327**	,721	-,287**		-,319**	-,330**	,719
DM	-,295		-,268	-,209	,811	,123		-,166	-,150	,816
Respiratory	-,173		-,068	-,107	,898	,201		,207	,245	1,278
RA	,015		-,161	-,096	,908	,129		,016	,014	1,014
Hospital-level										
Teaching hosp.	,502*			,734	2,083	1,230***			,510	1,665
VOP	**-,063**			**,083**	**1,086**	**,226****			**,045**	**1,046**
Surgery numbers	-,000			,000	1,000	,001***			,001	1,001
Mean orthopedic	,003*			,002	1,002	,002			-,006*	,994
Random effect										
Hospital-var		,340***	,354***	,373**			,839***	,832***	,839***	
ICC		3,4%	3,7%[a]	4,1%[a]			17,6%	17,4%	17,6%	

*P<0.05, **P<0.01, ***P<0.001.

A: As the relative variance of the clusters increases, the less likely you are to assume that the groups are similar (44).

Table 13: results multilevel analysis imaging

4.8 Outpatient visits

Patients with knee arthroplasty were having on average 3,71 outpatient visits in participating hospitals and 4,23 outpatient visits in non-participating hospitals. First, a logistic regression was performed to determine the effect of VOP on the number of outpatient visits. VOP had a significant decreasing effect on having three or more outpatient visits with knee arthroplasty. After the logistic regression, a multilevel analysis was performed. For knee arthroplasty, ICC was 9,7%, so multilevel analysis was suggested. Within the level 2 model, VOP has a non-significant decreasing effect on the number of outpatient visits. The chance of more than three outpatient visits decreases with 33,4% for knee arthroplasty patients treated in a VOP hospital.

Patients with hip arthroplasty were having on average 3,33 outpatient visits in participating hospitals against 3,56 in non-participating hospitals. The logistic regression showed a significant negative effect of VOP on more than three outpatient visits. After the logistic regression, a multilevel analysis was performed. ICC was 6,7%, so there was a small hospital level effect. Within the level 2 model, VOP has a non-significant decreasing effect on the number of outpatient visits. The chance of more than three outpatient visits decreases with 16% for hip arthroplasty patients treated in a VOP hospital.

	Knee					Hip				
	Logistic r	Level 0	Level 1	Level 2	Exp(B) Level 2	Logistic r	Level 0	Level 1	Level 2	Exp(B) Level 2
Individual-level										
Age	-0,021***		-0,023***	-0,022***	,978	-0,011**		-0,006	-0,007	,993
Gender	-0,005		0,026	-0,016	,984	0,130		0,125	0,123	1,131
Readmission	0,775*		1,078***	1,052**	2,865	1,436***		1,416***	1,407***	4,084
Hospital days	0,072**		0,058*	0,063**	1,065	0,046**		0,051**	0,055**	1,056
Cardiovascular	0,016		-0,022	-0,008	,992	-0,076		-0,153	-0,076	,927
DM	-0,177		0,015	-0,095	,910	-0,478		-0,387	-0,391	,677
Respiratory	0,013		0,021	0,040	1,040	0,024		0,118	0,093	1,098
RA	0,203		0,116	0,095	1,100	-0,408		-0,320	-0,357	,700
Hospital-level										
Teaching hosp.	-1,319***			-0,671	,511	-0,445			-0,384	,681
VOP	**-0,574*** **			**-0,406**	**,666**	**-0,376*** **			**-0,174**	**,840**
Surgery numbers	0,000*			-	1,000	0,000			-0,001	,999
Mean orthopedic	-0,072**			-0,007**	,993	-0,004**			-0,006*	,994
Random effect										
Hospital-var		0,593***	0,630***	0,594**			0,487***	0,491***	0,513***	
ICC		9,7%	10,8%	9,7%			6,7	6,8%[a]	7,4%[a]	

*P<0.05, **P<0.01, ***P<0.001.

A: as the relative variance of the clusters increases, the less likely you are to assume that the groups are similar (44).

Table 14: results multilevel analysis outpatient visits

5 Discussion

In this chapter, the results will be discussed, and limitations will be addressed. Lastly, an advice about the value-oriented care purchasing process will be given and recommendations for future research will be done.

5.1 Main results

In this report the impact of the value-oriented care purchasing process on outcomes and costs of knee and hip arthroplasty were identified. Results of the effects of VOP on outcomes and costs measures are all non-significant, however there are large effect sizes. These substantial effect sizes should be taken into account (48). Outcomes after knee arthroplasty show that patients treated in hospitals that participate in VOP have a non-significant higher chance of readmissions, infections, having more than five hospital days and more than two imaging activities. However, they also have a non-significant lower chance of revisions and having more than three outpatient visits. For hip arthroplasty, results show that patients treated in hospitals that participate in VOP experience a non-significant higher chance of readmissions, revisions, infections, more than five hospital days and more than two imaging activities but a non-significant lower chance of having more than three outpatient visits.

5.2 Discussion of results

The results from this study corresponded with outcomes of the study of Gabriel et al. (2019). This study did also not find significant results on the effects of VBHC on patient related outcomes. Lower pathway costs were identified for patients with hip arthroplasty by having physiotherapists and orthopedic surgeons working side by side (19). Physiotherapists were not included within this study, so this could not be compared. A clinical review about the effects of alternative payment models in total joint arthroplasty show that preliminary results of alternative payment models have shown promising results to reduce costs and improve quality of care by reducing hospital length of stay, decreasing readmissions, and a decreasing number of patients sent to rehabilitation facilities. Another study about bundled payment in Stockholm showed that there was a lower complication rate and a reduction in costs (49). However, it is difficult to compare these outcomes because bundled payments are not optimally working yet in the Netherlands. At this moment, within the Dutch healthcare sector, the first bundled payment reimbursement methods are working for chronic conditions such as Diabetes mellites and vascular risk management and results seem promising (50). However, for total joint arthroplasty the introduction of bundled payments is less optimally implemented. Financing is still fragmented because reimbursement is limited to hospital care. Rehabilitation is not included within the bundle and this results in an unclear picture of the care pathway for patients with total joint arthroplasty.

Quality improvement interventions are often labeled as black boxes (51). Quality improvement interventions have gained popularity in healthcare. The black box refers to the evaluation of quality improvement interventions. It is difficult to assume a simple, linear path between the quality improvement intervention and outcomes. To accurately assess the effectiveness of quality improvement programs such as VOP, there must be a greater understanding of the complexity of quality improvement work (52). Evaluations of these interventions show different results based on the research model used, because it is difficult to describe the relationship between the intervention, outcomes and context (52). Therefore, there is less evidence on the effectiveness of quality improvement interventions (51). This makes it also difficult to compare participating knee and hip arthroplasty hospitals with non-participating hospitals of the value-oriented care purchasing process, because it is possible that other hospitals are also participating in a value-oriented process outside Company X. A well-known VBHC cooperation in the Netherlands is Santeon. These are seven Dutch top clinical hospitals, working together to improve different care conditions based on the principles of VBHC. Two hospitals that are affiliated with Santeon are also affiliated with Company X' value-oriented care purchasing process for total joint arthroplasty. However, five Santeon hospitals are not affiliated with the value-oriented care purchasing group. This may weaken the results.

Within the logistic regression analysis, the effect sizes of teaching hospitals are sometimes estimated at ,000. It is difficult to estimate the effect of teaching hospitals on outcomes and costs measures because within the teaching hospitals often no (or a very low number) readmissions, revisions and infections occur because of the low number total joint arthroplasty patients. Teaching hospitals only appear in the non-VOP group. It is expected that teaching hospitals treat more severe patients, so normally a teaching hospital is an important control variable. However, because a low number of patients and events it is difficult to estimate the effect and therefore, logistic regression analysis is also performed without teaching hospitals as control variable; however, directions of the coefficients and significance do not differ. In the multilevel analyzes (hospital days, imaging, and outpatient visits), total joint arthroplasty patients treated in university hospitals do fall into both groups (0-5 hospital days or more than

5 hospital days, etc.). However, the academic hospitals are still only located in the non-VOP group. Multilevel analysis was also performed without teaching hospitals as control variable, but directions of the coefficients and significance do also not differ.

Patients are usually clustered within higher-level units such as hospitals. Patients clustered within a similar cluster may be more similar to each other than patients in other clusters (46). Multilevel models were developed to correct the dependency of patients within the same cluster (44). In this study, multilevel analysis was used for hospital days, imaging activities and outpatient visits. For readmissions, revisions and infections ICC was very low (<0,001%). This suggest that that all observations were independent from each other. (44) Despite, groups of patients were treated in the same hospital. The main reason for this was that the number of readmissions, revisions and infections was very low (2%). This makes it difficult to discover differences between clusters, because in some hospitals 10-20 total joint arthroplasties were performed. With this number of patients there were approximately one or two readmissions, revisions, and infections per hospital. Due to this low percentage, the percentage is sensitive to fluctuations. Therefore, binary logistic regression was used instead of multilevel analysis. However, directions of coefficients and effects of binary logistic regression and multilevel analysis do not differ. There is tried to create more events by combining readmissions, revisions, and infections into one negative outcome. However, multilevel analysis was still not suggested because of a redundant ICC and results did not chance.

5.3 Limitations of this study

There are some limitations of this study caused by a limited data set. An important aspect of Value-Based Healthcare is creating value around the patient (7). Creating value around patient care is often measured in PROMs. A limitation in identifying the impact of the value-oriented care purchasing process on outcomes and costs of knee and hip arthroplasty is the exclusion of PROMs in this study. In comparable studies PROMs were used as an important indicator of outcomes (22). However, PROMs were only available on hospital level instead of patient level. Therefore, this was not included in this study. The value-oriented care purchasing process has not resulted in an improvement in outcomes or costs, but it is possible that the value-oriented care purchasing process shows an improvement in PROMS. However, Gabriel et al. (2019) found no difference in PROMs after pathway redesign based on the principles of VBHC (19).

The study of Orthochoice in Stockholm also did not find a significant improvement in PROMs after the introduction of bundled payments (49).

In comparable studies, Charlson index score was often used as a control variable. Charlson index scores were not available within the Company X database. Instead of Charlson index score, relevant comorbidities were determined based on literature search and in collaboration with advisory physicians. These comorbidities were considered when in the previous year of the surgery, a declaration was found in Company X' database of one of the relevant comorbidities. The percentage of comorbidities should be higher because only declaration in the previous year were selected, but this was difficult to identify in the database. In this way most severe comorbidities were selected and there was assumed that when in the previous year no declaration exists, the comorbidity was under control. However, the effect of selected comorbidities on outcome and cost measures could have been larger.

Within the dataset, the reason for using antibiotics could not be identified. It is assumed that antibiotics within 30 days after surgery are most often used for wound infections. However, it is also possible that these antibiotics were prescribed for example for strep throat. The validity could be decreased with these assumptions. However, these assumptions do account for all patients and therefore, the effects will probably be similar between hospitals. It would be better to exclude certain antibiotics that are hardly used for wound infections. These could be identified using interviews or focus groups. However, within this study this was not possible due to time restrictions.

There are two other limitations due to data constraints in this study. The first limitation is that only the results of the first year after introducing the value-oriented care purchasing process are available. It is possible that effects are visible after a longer period. The second limitation of the available data was that information regarding the total care process of patients with knee and hip arthroplasty is missing. Information about the hospital care process is available. However, information regarding the revalidation process (home care, physiotherapist, etc.) is missing. As patients have a long revalidation process after undergoing knee or hip arthroplasty, information about the revalidation pathway is very useful in the knee and hip arthroplasty care pathway.

Relevant outcome and cost measures were identified based on a mini literature review. In the mini literature review certain studies and outcome and cost measures could have been missed. However, when certain studies have been missed and other outcome measures were used in that study, these outcome measures still were not considered in this study. This, because relevant outcome measures were identified based on counting. When outcome and cost measures only appeared once in the mini-literature review, they were not used in this study. So, if a different outcome or cost measure was used in a missed study, this outcome or cost measure was still not considered in this study. However, identifying outcome and cost measures based on comparable studies might result in missing relevant outcome and cost measures because comparable studies also only use measures that are available at that moment. So, it is possible that an outcome or cost measure is missed, however it is very likely that data of those measures was also not available for this study.

Opinions of hospitals, caregiver and patients are often mentioned in comparable studies. However, those were not considered in this study because those data could not be obtained. It is possible that when different, more qualitative outcome measures were used, results of the value-oriented care purchasing process could have been more positive.

5.4 Advice and future research

In this study there is found that outcomes in terms of readmissions, revisions and infections after knee and hip arthroplasty have not significantly improved after introduction of the value-oriented care purchasing process. Costs in terms of hospital days and imaging activities have also not decreased, however the number of outpatient visits is lower in comparison with non-participating hospitals. These outcomes do not show positive effects of the value-oriented care purchasing process. However, especially percentages of readmissions, revisions and infections after knee and hip arthroplasty are low. Therefore, it is difficult to reduce this percentages. Many changes are needed to decrease these percentages, and so far, this has not succeeded. To say something about disseminating value-oriented care purchasing process to other conditions, three recommendations are made.

First the effects of value-oriented processes need to be investigated for a longer period. It is possible that an improvement in outcomes and a reduction of costs will be visible within the long term, so results of the years 2019 and 2020 needs to be examined. Value-oriented processes for different conditions within Company X such as cataract or artery disease should also be investigated. It is possible that Company X' value-oriented processes for different conditions indicate more positive effects on selected outcome measures.

The second recommendation is to select different outcome measures. As already discussed in the part above, it is difficult to identify the effectiveness of a quality or value improvement program. Selecting different outcome measures could possibly change results. Subjective outcome measures were not used in this study. Within the value-oriented care purchasing process, there is much attention for PROMs. Therefore, it is suggested to investigate the effect of the value-oriented care purchasing process on PROMs. Opinions of medical specialists, managers and patients were not considered in this study. If Company X attaches great importance to these subjective measures, more research needs to be done. This could be done by doing qualitative research instead of quantitative research.

The third recommendation is to try to obtain data from the total knee and hip arthroplasty care pathway including the rehabilitation process. Care is moving from second line to first-line care. This shift probably results in a reduction of costs. This reduction in costs is not included within this study. It would be interesting and valuable to further investigate this.

Different recommendations for further research are made. Company X should define which outcomes are relevant to the decision-making process around value-oriented care purchasing. If qualitative outcomes are of primary interest, then future research should focus on different outcome measures such as PROMS and on qualitative outcome measures identified with interviews. If instead quantitative outcomes are of primary interest, then the outcome and cost measures should be examined for a longer period and outcome and cost measures should be evaluated for other value-oriented care process of Company X. It is also suggested to include the rehabilitation pathway of total joint arthroplasty patients. Both research tracks can also be performed in parallel to get an even broader view of the impact of value-oriented purchasing.

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7. Appendixes

7.1 Appendix 1: Search terms mini literature review

Search terms in Google scholar, Pubmed and Scopus	
Search terms outcome measures	**Search terms control variables**
Knee replacement	Knee replacement
Hip replacement	Hip replacement
Knee and hip replacement	Total joint arthroplasty
Knee and hip arthroplasty	Total joint replacement
Total joint arthroplasty	Total joint implants
Total joint replacement	Total joint protheses
Total joint implants	Value based healthcare
Total joint protheses	Readmission
Value based healthcare	Admissions
VBHC	Revision
Bundled payment	Reoperations
Integrated practice units	Wound infection
Value of care	Infections
Cost drivers	Hospital days
Outcome measures	Mortality
Output rewarding	Imaging
	Outpatient visits
	Regression
	Univariate analysis
	Multivariate analysis

7.2 Appendix 2: Decision table comorbidities

Comorbidities	Counting
Cardiovascular diseases	5
Diabetes mellites	5
Rheumatoid arthritis	5
Respiratory diseases	7
Genitourinary diseases	2
Gastrointestinal illness	2
Hypertension	2

7.3 Appendix 3: output unconditional model readmission

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	2,262E-10[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	,000[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

7.4 Appendix 4: output unconditional model revisions

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	,000[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

Random Effect

Revisie	Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
						Lower	Upper
1	Var(Intercept)	,000[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

7.5 Appendix 5: output unconditional model infections

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	,000[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	2,353E-12[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

7.6 Appendix 6: output unconditional model events

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	7,702E-10[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.

Random Effect

Random Effect Covariance	Estimate	Std. Error	Z	Sig.	95% Confidence Interval	
					Lower	Upper
Var(Intercept)	2,353E-12[a]	.	.	.	.	.

Covariance Structure: Variance components

Subject Specification: Ziekenhuisnr

a. This parameter is redundant.