Wait Times in Hip and Knee Replacement: Single-Entry Model and Prioritization

By

© Anh Thu Thi Vo

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Abstract

The single-entry model (SEM) in healthcare consolidates waiting lists through a single point-of-entry and patients can see the next available surgeon from a pooled available provider based on the patient's urgent levels. Prioritization is used to ensure that patients with higher urgent levels may access care quickly. The SEM for hip and knee replacement surgery in the Eastern Health region of Newfoundland and Labrador showed a reduction in wait times for consultation by priority levels. Little is known about the improvement in wait times for surgery and the chance of receiving consultation and surgery within the national benchmarks by priority levels. This study aimed to examine the SEM's role in timely access to orthopedic services and evaluate an association between factors and receiving consultation and surgery within the national benchmarks through the SEM.

Survival analysis was conducted to estimate wait times, examine factors impacting wait times for hip and knee replacement. The data used were adult patients referred to the Orthopedic Central Intake clinic in the Eastern Health region for a total hip or knee arthroplasty assessment between 2011-2019. Logistic regression analysis was used to explore the association between these factors and the receiving consultation and surgery within benchmarks.

The study revealed that hip or knee replacement patients with high urgent had more likely to see an orthopedic surgeon for consultation than those with low urgent. Hip or knee replacement patients with priority 1 were more likely to have a consultation within 90 days than their counterparts. Priority levels were not significantly related to the likelihood of having surgery since the decision to surgery was made for both hip and knee. The likelihood of receiving a knee replacement surgery within 182 days was nonsignificant among patients with priority 1,

priority 2, and priority 3, while hip replacement patients with priority 3 were more likely to have surgery within 182 days than those with a high priority level.

Choosing the next available surgeon shortened wait times for consultation and improved the likelihood of receiving consultation within 90 days. However, this choice was less likely to have surgery within 182 days than choosing a specific surgeon. Incomplete initial referral forms prolonged wait times for consultation but insignificantly impacted the probability of having consultation within 90 days. Patients with knee osteoarthritis were less likely to have consultations within 90 days than patients with other arthritis disorders.

This study explored the timely improvement of access to consultation for hip and knee replacement by priority levels and factors impacting wait times through the SEM. An association between wait time for surgery and priority levels was not found in this study, whereas hip replacement patients with low priority were more likely to receive surgery within the benchmark of 182 days than those with high priority. Further studies are needed to investigate this.

Key words: Single-entry model, central intake, priority levels, prioritization, triage, total hip replacement, total knee replacement, total hip arthroplasty, total knee arthroplasty.

General Summary

The single-entry model (SEM) in hip and knee replacement improves access to care through the system where referrals are pooled and assigned to the next available surgeon based on the patient's urgency. Prioritization may allow patients with higher priority to timely access to healthcare services. It is worth examining the reduction in wait times through the SEM by priority and the association between influential factors and receiving consultation and surgery within the benchmarks.

The thesis concluded that patients with higher priority levels had shorter wait times for consultation and shorter total wait times from referral to surgery than those with lower priority levels through the SEM in Eastern Health, while an improvement in wait times for surgery by priority was not significant. This thesis also revealed choosing the next available surgeon, knee osteoarthritis, and patient's urgency that significantly impacted receiving consultation and surgery benchmarks.

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Candidates' Contribution to Work

The candidate was responsible for the preparation, writing and submission of the ethical applications. The candidate conducted a literature review and data analysis from a linkage administrative data between the Orthopedic Central Intake database and the Total Joint Assessment Centre database. The candidate was responsible for writing, interpretation of findings from the thesis. Dr. Yanqing Yi designed the study and methods, provided advice on data analysis, interpretation of the results, and the structure of manuscripts.

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List of Abbreviations

CHA: Canada Health Act

CIHI: Canadian Institute for Health Information

COA: Canadian Orthopedic Association

DSU: Day Surgery Unit

EASE: Ensuring Access and Speedy Evaluation

HKPT: Hip and Knee Replacement Priority Criteria Tool

HRQoL: Health-Related Quality of Life

IMGs: International Medical Graduates

KM: Kaplan Meier

LOS: Length of Stay

MAPT: Multi-Attribute Prioritization Tool

MAWT: Maximum Acceptable Wait Time

MCP: Medical Care Plan

OAC: Orthopedic Assessment Clinic

OASIS: Osteoarthritis Service Integration System

OCI: Orthopedic Central Intake

OECD: Organization for Economic Cooperation and Development

PWTG: Patient Wait Times Guarantees

ROC: Receiver Operating Characteristic

SEM: Single-Entry model

TC LHIN: Toronto Central Local Health Integration Network

TJAC: Total Joint Assessment Center

TW: Total Wait Time

VAS: Visual Analogue Scale

WCIS: Winnipeg Central Intake Service

WCWL: Western Canada Waiting List

WOMAC: Western Ontario and McMaster Universities Osteoarthritis

WT1: Wait Time for Consultation

WT2: Wait Time for Surgery

Chapter 1. Introduction

Canada's publicly funded healthcare system provides universal coverage for medically necessary healthcare services, ensuring that all eligible residents in provinces and territories have access to medically necessary hospital and physician services without financial barriers. The Canada Health Act (CHA) is "Canada's federal legislation for publicly funded health care insurance".[1] The Act provides fundamental criteria (including public administration, comprehensiveness, universality, portability, and accessibility) with which provinces and territories have to abide to access federal funding for health care insurance plans.[1]

However, long wait times for elective care (such as hip and knee replacement) is problematic in Canada. According to the Canadian Institute for Health Information (CIHI) (2017),[2] Canada has the highest wait times for specialists and non-emergency surgeries compared to other Organization for Economic Cooperation and Development (OECD) countries. Some plaintiffs in Quebec and British Columbia stated that because the publicly funded health care system requires some patients to wait for medically necessary services, particularly in non-emergency situations, patients can suffer serious psychological and physical complications.[3,4] In Chaoulli v. Quebec (2005), Chaoulli stated that the prohibition on private health insurance may violate Section.7 of the Canadian Charter of Rights and Freedoms.[3] However, some studies showed that the two-tier system was unlikely to reduce wait times, whereas it may lead to an increase in wait times and a reduction in health care quality in the public system.[5,6,7]

1.1. Wait times for hip and knee replacement surgery

1.1.1. Long wait times for hip and knee replacement

The long wait times for hip and knee replacement surgeries have been problematic in Canada. More than half of patients wait over 272 days (nine months) for their hip or knee

replacement surgeries since the decision to surgery was made (WT2).[8,9] According to the reports of Fraser Institute, a think-tank that is pro-private health insurance in Canada's health system, from 2006-2019, the national median total wait times (TW) from referral to surgery reduced slightly to 274 days in 2019 [10] from 282 days in 2006.[11] In Newfoundland and Labrador (NL), the percentage of patients meeting the benchmark of 182 days for joint replacement surgeries dramatically rose from 75% in 2010 to 96% in 2014, but decreased to 88% in 2018 for hip replacements; and from 67% in 2010 to 92% in 2014, and dropped to 75% in 2018 for knee replacements.[12,13] Moreover, the 2006-2019 reports from the Fraser Institute illustrated that the median TW that NL patients had to wait increased from 258 days in 2006 to 340 days in 2017, [11,14-25] but reduced to 218 days in 2019.[10]

Wait times for hip and knee replacement vary amongst provinces. In fact, multiple factors can account for differences in wait times across the country, including how wait times are measured, and the capacity to provide adequate resources that meet the demand for these types of surgeries.[26] The percentage of patients receiving surgery within 182 days improved by at least 5% for hip and knee replacement surgeries in British Columbia and NL from 2010 to 2018. In Nova Scotia, the percentage of the patients having knee replacement surgery within 182 days increased from 38% in 2016 to 47% in 2018. In contrast, the proportion meeting benchmarks in other provinces decreased or remained unchanged.[12]

1.1.2. Negative impacts while waiting for hip and knee replacement surgery

Long wait times for hip and knee replacement surgery may be the cause of an increase in medical and non-medical costs and a deterioration in health-related quality of life (HRQoL). The waiting time for hip and knee replacement increases the burden of medication costs and unemployment.[27-31] The total cost of medications for patients with long wait times is higher than

those with short wait times.[31] Fielden et al.[28] showed that the total mean cost including medical cost, societal cost (e.g., lost income and time away from normal activities), and personal expense (e.g., help and support cost required during disability) for the group that has been waiting for over six months for surgery is greater than for those in the group who have been waiting for under six months. However, Quan et al.[29] demonstrated that waiting for hip or knee replacement surgery is not associated with more physician claim costs for both pre-surgery and post-surgery. Moreover, Bohm et al.[27] identified that approximately 20% of patients in the workforce waiting for a hip replacement have to be off of work due to having negative health consequences. In terms of cost-effectiveness, delaying total hip and knee replacement was not a cost-effective strategy.[30,32,33] Mather et al.[30] showed that total knee arthroplasty with little delay might be a cost-saving strategy. Mota[33] found that delayed total hip replacement would not be cost-effective at any levels of patient's condition.

Patients are suffering negative health consequences while experiencing long wait times for surgery. They may experience difficulties with mobility, pain, and managing daily living.[27,34,35] Desmeules et al.[34] showed that patients waiting for surgery for over nine months have worse pain and function scores, as well as worse physical functioning compared with those who have shorter wait times. Similarly, Fielden et al.[28] demonstrated that patients with longer waits for hip and knee arthroplasty may have poorer physical function. However, patients undergoing their procedure within the first six months do not experience a deterioration of pain or a reduced functional capacity.[35]

In addition to having a reduced quality of life for those with long wait periods for surgery, patients may suffer adverse pain, reduced functional capacity, and dissatisfaction after surgery.[36-39] Desmeules et al.[36] revealed that patients waiting for surgery longer than nine months have the lowest scores on pain, activity limitation, and physical function related quality of life six months

after surgery compared with patients waiting for shorter periods. Similarly, Mahon et al.[39] showed that hip replacement patients waiting more than six months for surgery had clinically important losses in health quality of life and mobility compared to those had a surgery within six months. Additionally, a likelihood of achieving better than expected post-surgery functional outcome reduces by 8% for each month a patient waits for surgery.[37] Scott et al.[38] identified that the increasing wait times for surgery might increase the number of patients who experience a worse health quality of life. Although patients with worse health states had satisfaction rates improved significantly after their replacement surgeries, they have lower quality of life and satisfaction scores than those less worse health quality of life in pre-surgery.[38]

1.2. Ongoing initiatives to reduce wait time for hip and knee replacement surgery

Long wait times for hip and knee replacement may deteriorate health related quality of life and may have adverse outcomes for patients, such as anxiety, pain, or stress. Additionally, long waits for surgery can increase the burden on the healthcare system. Therefore, the federal government and provincial health authorities have made efforts to improve access to healthcare services and reduce wait times for hip and knee replacement surgery.[40]

1.2.1. At the federal government level

During the past few decades, the Canadian government has made considerable efforts to reduce the shortage of healthcare resources, improve access to these resources and decrease wait times.

In 2004, Canada's First Ministers agreed on timely access to healthcare as a priority in their 10-Year Plan to Strengthen Health Care.[1,40] About $41.3 billion was allocated to provinces and territories on per capita basis over a period of ten years until 2014. This included $35.5 billion in Canada Health Transfers, $5.5 billion for specific initiatives to reduce waiting time in

provinces and territories, and $500 million for diagnostic and medical equipment. This fund was allocated into several priorities: training and hiring more healthcare professionals, clearing backlogs, increasing capacity for health region centers, and developing systems to manage wait times.[1,40,41]

In 2007, Budget 2007 invested an additional $1 billion in support of Patient Wait Times Guarantees (PWTG), including $612 million for the PWTG Trust, $400 million for guarantee-related investments via Canada Health Infoway, and up to $30 million for the PWTG Pilot Project Fund that allowed provinces to pilot and test approaches to promote PWTGs.[1,40,41]

On December 12, 2005, the Health Ministers announced evidence-based national benchmarks for the five priorities: cardiac care, cancer care, sight restoration, joint replacement, and diagnostic imaging.[40] A benchmark is defined as "evidence-based goals that each province and territory will strive to meet, while balancing other priorities aimed at providing quality care to Canadians. Benchmarks express the amount of time that clinical evidence shows is appropriate to wait for a particular procedure".[42(p34)]

The National Standards Committee of the Canadian Orthopedic Association (COA) recommended benchmarks for maximum acceptable wait time (MAWT). The MAWT has two intervals: an MAWT benchmark within 90 days for consultation (from referral to consultation) and an MAWT benchmark within 6 months for surgery (from the decision date for treatment to the date of surgery).[43]

1.2.2. At the provincial government level

A comprehensive wait time management system is an important tool for management of wait times.[44] Electronic patient records, and booking systems for appointment scheduling for preoperative care, surgery, and postoperative care are tools to manage accurately wait time data.

Reports that are updated to the federal website and provincial health authorities' websites are critical because clinicians and surgeons can identify actual progress and capacity. It is vital to develop wait time webpages where general physicians and patients can assess and be well informed about surgeons' wait times.[45] The CIHI has a responsibility for receiving reports about progress on wait times from provinces and territories.[40]

A central intake system, known as a SEM, is also an innovation for management of wait times.[44] In traditional models, each surgeon receives referrals and manages their own waiting list. This means that when a patient is referred to a surgeon whose appointment slots are all unavailable, the patient has to wait until a vacancy is available, even if another surgeon is available. As a result, that patient cannot have an appointment with the next available surgeon.[41] SEMs have been implemented in healthcare to avoid the disadvantages of the traditional models. In the SEM, multiple queues are consolidated into a single queue through a central intake system, patients are triaged for priority, and patients can meet the next available surgeon from a pool of participating surgeons.[46-48] SEMs are implemented to manage wait times of referrals and to assist patients who are awaiting access to a service.[46]

Some provinces including Alberta,[49-51] British Columbia,[52,53] Manitoba,[46,48,54] Ontario,[55] and Nova Scotia[56,57] implemented SEMs to reduce long wait times for hip and knee replacement surgery.

In NL, in order to respond to the public's expectations about more timely access to healthcare, shorter wait times, and comprehensive information related to wait times for hip and knee replacement surgery, the provincial government established strategies to improve access to healthcare services. In 2011, the Government of Newfoundland and Labrador committed to deal with wait times for total hip and knee replacement surgery. In 2012, the provincial government developed a strategy on reducing wait times for hip and knee replacement surgery, enhancing the

utility of orthopedic services, and improving the flow of patient journey. Additionally, the government invested more than $140 million to improve wait times.[58] A provincial five-year strategy to reduce wait times for hip and knee replacement surgeries had five goals. These goals included: to shorten wait time for consultation and improve orthopedic assessment and services for patients with hip and knee replacement surgeries; to improve the capacity of hospital services for total joint replacement surgeries; to address the backlog of patients who were waiting for total joint arthroplasty; to improve the collection and utility of wait time data of hip and knee replacement surgeries; and to reduce the number of patients requiring total joint replacement surgery henceforth.[58]The Department of Health and Community Services coordinated with experts, orthopedic surgeons, and general physicians in three health regions: Eastern, Central, and Western Health to establish the Strategy to Reduce Hip and Knee Joint Replacement Wait Times. Eastern Health redesigned the referral process from general physicians to specialists and developed a centralized intake clinic along with the Orthopedic Central Intake (OCI) priority classification guideline for orthopedic services.[59] The priority classification guideline may improve long wait times for a consultation with an orthopedic specialist. The SEM provides a standardized referral tool for orthopedic services.[59] The referral priority classification guideline is considered a method that surgeons can use to manage wait times for consultation based on the patient's urgency level.[60] Additionally, Western Health implemented an Orthopedic Central Intake (OCI) clinic in 2013 to manage wait times for hip and knee replacement surgery.[61]

1.3. Rationale of the study

The SEM for hip and knee replacement surgery in Eastern Health showed improvements in timely access to orthopedic specialists from 2011 to 2014. The 2011-2014 annual reports from Eastern Health showed that from 2012 to 2014, the median wait time for consultation of priority

1 and 2 reduced from 95 days to 47 days, and that of priority 3 and 4 dropped from 182 days to 123 days.[62-64] The 2011-2018 annual reports from Eastern Health and the 2019 report from CIHI demonstrated that from 2008-2015, the percentage of total joint replacement surgery meeting the national benchmark of 182 days increased to 93% for hip and 89% for knee, but these figures gradually dropped to 87% for hip and 73% for knee in 2018.[12,62-68]

However, some challenges can exist with the use of the referral priority classification. First, if many new patients with a high urgency level are seen by orthopedic surgeons for consultation and surgery, lower urgent patients can never reach the top of the waiting list. Second, if patients with low priority scores are guaranteed to access orthopedic services within maximum acceptable wait times, some of them will bump patients with severe conditions. Unfortunately, the 2015-2019 reports did not provide any information about wait time consultation by priority as previous reports.[65-69] As a result, the improvement of timely access to orthopedic specialists through the SEM since 2015 was not examined carefully. Besides, the OCI database has not been linked to the hospital database in Eastern Health. Therefore, it is not well-known whether patients with lower priority levels can receive surgery within the national benchmark of 6 months without a linking the OCI and hospital databases.

Moreover, the median wait times from the provincial wait time system may be unlikely to reflect actual wait times for patients in need of hip and knee replacement in Eastern Health. Although the patient preference,[70-72] age,[70] and an incomplete referral form[73] can result in prolonging wait times for consultation, wait times for surgery and the median wait times from patients whose consultations or surgeries are delayed due to personal reasons are not included when determining the median wait times in the provincial wait times system.[74] Additionally, these influential factors in referral choices for hip and knee replacement surgery have not yet been included in Eastern Health annual reports.

Furthermore, an estimation of the total wait times for hip and knee replacement in Newfoundland and Labrador currently has certain gaps. First, although total wait times can provide evidence whether or not overall wait times can be shortened, the total wait times for Newfoundland and Labrador patients with hip and knee replacement surgery are currently estimated based on only surveys from the Fraser Institute. These surveys had low response rates of 33% in 2006[11] to 17% in 2019.[10] Second, none of studies or reports examined the total wait times for hip and knee replacements in Newfoundland and Labrador through a SEM in place.

Therefore, a secondary data analysis study is necessary to evaluate the role of the SEM to improve timely access to healthcare services for hip and knee replacement surgery. This study will also validate the priority classification for referral at Eastern Health and examine main factors that are likely to impact wait times in the SEM.

1.4. Research objectives

1.4.1. The primary objectives of this thesis

1) To estimate the median wait time for consultation, the median wait time for surgery, and the total median wait time from the initial referral to surgery in hip replacement surgery and in knee replacement surgery by prioritization status.
2) To examine the impact of factors including age, patient's preference (a specific surgeon versus the next available surgeon), diagnosis, incomplete referral form, priority levels, and year periods on wait time for consultation, wait time for surgery, and a total wait time from referral to surgery.
3) To examine an association between factors and receiving a consultation within MAWT of 90 days; between factors and the receiving surgery within the national benchmark of 182 days.

1.4.2. The secondary objectives of this thesis

1) To examine the percentage of patients with hip replacement surgery and knee replacement surgery having a consultation within an acceptable timeframe according to OCI priority classification of Eastern Health in each priority group.
2) To examine the percentage of patients who had seen surgeons for consultations within the MAWT of 90 days recommended by COA and the percentage of patients who had surgery within the national benchmark of 182 days in hip replacement surgery and knee replacement surgery by prioritization status.
3) To compare the total median wait time between hip and knee replacement in each priority group

Chapter 2. Literature review

This chapter provides a review of the literature regarding wait times for hip and knee replacements and the roles of priority classifications and the SEM in managing wait times for this field. The chapter has five main sections. Section 2.1 discusses the definition of wait times for hip and knee replacement used across Canada. Section 2.2 outlines the role of priority classification in improving wait times. Section 2.3 explores the role of the SEM in improving timely access in healthcare services. Section 2.4 reveals gaps existing in the literature. Section 2.5. summarizes the literature review.

2.1. Wait time definitions

Each province has its own wait time registry to collect, and monitor wait times. Data collection to facilitate wait time measurement is necessary to compare access to healthcare services across jurisdictions.[44] Wait times for hip and knee replacement surgery have two intervals: 'wait for consultation' and 'wait for surgery'.[13,45,46,58,75-77] **Table 2.1** demonstrates how provinces measure wait times for consultation (WT1 – a period from the date when a referral is received by a central intake or when a referral is sent by a family physician to the date when a patient has a consultation with a surgeon), and wait times for surgery (WT2 – the period from the date when a surgeon and the patient decide to treat to the date when that patient receives the surgery); and how the provinces describe and report wait times for hip and knee replacement surgeries on their wait times systems.[45,48,58,75-79]

Measures to describe wait times vary across jurisdictions.[44] Most provinces report mean[76] or median wait times for surgery.[13,45,75,77,78] Some provinces also use other statistics, including 90th percentiles, the percentage of patients receiving surgery within the national benchmark,[13,45,75-77,79] the number of surgeries completed,[13,77-79] and the number of patients waiting for surgery.[75,79]

Additionally, only Ontario reports average wait times and the percentage of patients receiving consultation and surgery within target wait times according to priority levels.[76]

There is no information regarding total wait times (TW) on provincial wait times webpages. Although the Fraser Institute estimated the TW from referral to surgery, these medians of TW are based on surveys that have low response rates, with only 24% responses in Canada on average. In Newfoundland and Labrador, the response rate was from 33% in 2006[11] to 17% in 2019[10], but the sample sizes were small, with 13 to 19 questionnaires mailed to surgeons in the province.[10,11,14-25]

Table 2.1. Environmental scan of wait times reports in Canada: Ontario (ON),[76] Manitoba (MB),[78] Nova Scotia (NS),[45] Alberta (AB),[77] Saskatchewan (SK),[79] Newfoundland and Labrador (NL),[13] and British Columbia (BC)[75]

	ON[76] (in days)	**MB[78] (in weeks)**	**NS[45] (in days)**	**AB[77] (in weeks)**	**SK[79] (in days)**	**NL[13] (in days)**	**BC[75] (in weeks)**
Wait for consultation (WT1)	Start time: date when the surgeon's office or central intake received the referral End time: date when a patient has a first consultation with a surgeon					Start time: date when a patient is referred to a surgeon End time: date when a patient has a first consultation with a surgeon	
Wait for surgery (WT2)	Start time: date when a surgeon and a patient decide to surgery End time: date when a patient receives surgery						Start date: date when a booking form is received by the health authority End date: date when a patient receives surgery
Describe wait times	- Average - Percentage surgeries within the target times according to priority level	- Median - Number of surgeries completed	- Median - 90th percentile	- Shortest 25% - Average - 90th percentile - Number of consultation and surgeries completed	- Number of patients receiving surgery - Percentage of surgeries within target time - Number of patients waiting for surgery - Percentage of patients waiting > 3 months	- Median - 90th percentile - Percentage of surgeries within national benchmark of 182 days - Number of procedures completed	- Median - 90th percentile - Cases waiting for surgery
Reports	WT1, WT2	WT2	WT1, WT2	WT1, WT2	WT2	WT2	WT2

2.2. The role of priority classification in improving timely access in healthcare services

The inadequate capacity of hospitals to respond to an increased demand for hip and knee replacement can cause long wait times for access to hip and knee replacement surgery. Therefore, it is necessary to ensure that patients who have the most urgent need for surgery receive surgeries in a timely manner before those with less urgent needs. To date, many countries use priority criteria and maximum acceptable waiting times according to priority categories to manage wait times in hip and knee replacement surgery. However, a waiting list categorization has not ensured that patients will receive their procedures earlier in some countries such as the UK,[80] Spain,[81] and Australia.[82] This requires a validated prioritizing system that is used to evaluate more accurately the severity of symptoms in hip and knee replacement patients and to manage the waiting list with clinical equity.[80-82]

In Australia, the Victorian Department of Health and Human Services developed urgency categories for elective surgery.[83] Orthopedic surgeons triaged patients into category 1 (urgent), category 2 (semi-urgent), or category 3 (non-urgent). While patients with category 1 would receive their surgery within 30 days, patients with category 2 would have a surgery within 90 days. Additionally, patients with category 3 might have surgery within 1 year or at some time in the future.[84,85] However, Russell et al.[84] identified some issues existing in that prioritization. Firstly, there was an imbalance between the high demand for hip and knee replacement surgery and the capacity of healthcare system to deliver services for patients requiring hip and knee replacement surgery. Secondly, categorizing patients as category 2 in preference to category 3 increased. As a result, not all patients will receive treatment within the recommended acceptable wait times.[82] Therefore, the Victorian Department of Health and Human Services developed a multi-attribute prioritization tool (MAPT) to accommodate current urgency categories. The

MAPT comprised eleven question domains that were used to evaluate patients' conditions regarding pain and physical function, psychological health impacts, economic effects, and recent deterioration. The MAPT score is categorized into three priority levels: a score of 0-20 (low priority) indicating a preferable non-surgery treatment, 21-60 (middle priority) indicating a surgery required, and 61-100 (high priority) indicating an urgent surgery required.[87] This new prioritization tool improved timely access for patients needing hip and knee replacement surgeries.[86,87]

Similarly, a prospective observational study compared real WT2 with priority criteria scores in six public teaching hospitals belonging to the Basque Health Service-Osakidetza in Spain. The study team developed a priority tool, including point scale ranges of 7-9 (urgent), 4-6 (preferent), and 1-3 (ordinary level).[81] Escobar et al.[81] showed that although there were significant differences in the mean scores of Western Ontario and McMaster Universities (WOMAC) domains: pain, functional limitation, and stiffness according to priority levels, there was not an association between the three levels of priority scores and categories of wait times on the waiting list comprising < 3 months, 3-6 months, and > 6 months. In fact, patients were not placed in the queue with clinical equity, leading to a nonsignificant difference in priory scores among wait time categories.

In the UK, a longitudinal study assessed whether patients with hip and knee replacement surgery are triaged on the basis of their clinical severity, pain, and loss of functionality.[80] The study used the visual analogue scale (VAS), the Oxford hip or knee score and the WOMAC Orthopedic Arthritis index to measure current pain, and severity of osteoarthritis symptoms, respectively. Moreover, patients would be interviewed at home at baseline and at 6 months, as well as by mailing questionnaires at 3 and 9 months or until patients receive surgeries.

Subsequently, patients on the waiting list were assigned a priority score according to their urgency including: 1 (most urgent), 2 (very urgent), 3 (urgent), or 4 (routine).[80] McHugh et al.[80] revealed that there was no relationship between priority levels and wait times on the waiting list. Moreover, there were no differences in VAS, WOMAC, and Oxford hip and knee scores between patients having earlier surgeries and their counterparts. This was because orthopedic surgeons in the study did not use any validated priority tool to triage patients on the waiting list.[80]

In Canada, some provinces break down the national benchmarks by priority. Patients with the most urgent level will receive surgeries earlier, while those at the lowest priority level can have surgeries later but within maximum acceptable wait times. The two priority classifications are priority for surgery and for referral.

2.2.1. Priority classification for surgery

A priority classification for surgery is a tool that an orthopedic surgeon can use to prioritize patients for a hip and knee replacement surgery and manage waiting lists. In Canada, the Western Canada Waiting List (WCWL) project developed prioritization tools for five settings including hip and knee replacement, cataract removal, general surgery, children's mental health services, and magnetic resonance imaging.[87] Particularly, the hip and knee replacement priority criteria tool (HKPT) is one of five tools established by the WCWL in order to provide a transparent and impartial method for prioritizing patients with hip and knee replacement on waiting lists.[88] The HKPT consists of 7 criteria, with 3 to 4 levels for each of criteria, measuring on pain (pain on motion, pain on rest), functional limitation, physical examination, potential progression of the disease, and threat to role and independence.[88] Maximum waiting times in weeks in accordance with priority criteria scores for hip and knee replacement surgery are shown in **Table 2.2**.

Table 2.2. Maximum waiting times in weeks correspondence with priority criteria scores for hip and knee replacement surgery[88]

Priority criteria scores	Maximum acceptable wait times
≤ 45	52
46-65	36
66-80	16
≥ 81	8

Furthermore, Saskatchewan,[90] British Columbia,[91] Ontario,[92] and Newfoundland Labrador[60] developed their prioritization tools modified from the WCWL tools. The maximum WT2 for hip and knee replacement by priority scores in Saskatchewan, British Columbia, Ontario, and Newfoundland and Labrador are provided in **Table 2.3**.

Table 2.3. Priority levels and maximum WT2 in weeks for hip and knee replacement in Saskatchewan,[90] British Columbia,[91] Ontario,[76] Eastern Health[62]

Priority level	Time frame			
	SK	BC	ON	NL (Eastern Health)
I	Within 24 hours	Within 2 weeks (14 days)	Within 7 days	Within 1 week (7 days)
II	Within 24 hours-3 weeks (21 days)	Within 4 weeks (30 days)	Within 7-42 days	Within 1-3 weeks (7 days-21 days)
III	Within 3 - 6 weeks (21 days-42 days)	Within 6 weeks (42 days)	Within 56-84 days	Within 3-6 weeks (21 days-42 days)
IV	Within 6 weeks to 3 months (42 days-90 days)	Within 12 weeks (90 days)	Within 182 days	Within 6 weeks – 3 months (42 days-90 days)
V	Within 3 - 6 months (90 days-182 days)	Within 26 weeks (182 days)	n/a	Within 3-6 months (90 days-182 days)
VI	> 6 months (>182 days)	n/a	n/a	6-12 months (182 days-365 days)

In Canada, there was not an association between priority levels and WT2. In fact, in Ontario the percentage of patients with priority 2 receiving their surgery within the target of 45 days reduced from 60% in 2008/2009 to 51% in 2016/2017. Similarly, the percentage of patients with priority 3 receiving their surgery within the target of 84 days reduced from 63% in 2008/2009 to 59% in 2016/2017. In contrast, this figure in patients with priority 4 – (non-urgent surgery with a target of 182 days) remained stable at approximately 80%.[76] In Saskatchewan, about 54% of patients received surgery within 3-6 weeks (21 days-42 days) while 74% of patients received their surgery within 3-6 months (90 days-182 days).[79] To date, only Ontario and Saskatchewan reported WT2 by priority levels on their wait time report system, while other provinces report their wait times in all priority levels combined.

2.2.2. Priority classification for referral

Although priority classification for elective surgery such as hip and knee replacement are used in Australia,[83,84] New Zealand,[93] Spain,[81,94] and the UK,[80] there is little information on the priority classification for referral in the literature.

In Canada, the Western Canada Waiting List (WCWL) project developed a priority referral score for hip and knee replacement that primary care providers may use to ensure that patients with more urgent levels can meet a specialist for a consultation sooner than those with lower levels. This priority referral score has been modified from the WCWL prioritization tool that is used for making decision to proceed with surgery. Moreover, the referral tool has been designed with a standard referral letter form. The standard referral letter may be modified to comprise information according to orthopedic surgeons' recommendations.[95]

Changing the mindset of healthcare providers is one of the challenges in the WCWL Hip and Knee Referral tool.[94] Wait times for referral correspondence with priority levels are managed

by every clinic and hospital across the provinces. Ontario establishes their priority levels and target times from referral to consultation.[76] The Eastern Health region of Newfoundland and Labrador also developed a routine priority classification that their central intake clinics have used to triage patients to a surgeon for consultation.[60] **Table 2.4** and **Table 2.5** demonstrate target times for consultation in accordance with each priority level in Ontario and in Eastern Health, respectively.

Table 2.4. Priority levels and target WT1 in Ontario[76]

Priority level	Target time for consultation
Priority 1	Not included in wait times data
Priority 2	Patient sees surgeon within 30 days of referral received
Priority 3	Patient sees surgeon within 90 days of referral received
Priority 4	Patient sees surgeon within 182 days of referral received

Table 2.5. Priority levels and target WT1 in Eastern Health[60]

Priority level	Target time for consultation
Priority 1	Appointments booked within 45 days
Priority 2	Appointments booked within 90 days
Priority 3	Appointments booked within 6 months (182 days) - < 12 months (365 days) of receipt of complete referral
Priority 4	Patients are not appropriate for orthopedic surgical consultation at that time

However, a priority classification for referral has not been implemented provincially across Canada. Apart from Ontario, time targets for referral for each priority level have not been shown in provincial wait times systems. In most provinces, urgency is determined by conversations between the patient and the family physician before seeing the surgeon. If the patient's condition changes at any time during the process, it is the policy of all hip and knee arthroplasty centers to encourage the family physician to communicate this and raise a flag of

increased urgency. In this way, the hip and knee arthroplasty centers can do their best to accommodate the needs of the patient.[96]

A few studies focus on evaluating the relationship between priority levels and wait times for consultation. In terms of provincial websites, only the wait times system in Ontario provides both intervals, including target WT1 and target WT2, as well as a percentage of the patients receiving consultations and surgeries within targets.[75] On average, 86% of patients with priority 2, 75% of patients with priority 3, and 93% of patients with priority 4 have a consultation with a surgeon within the time target.[76] Although the Eastern Health region in Newfoundland and Labrador has implemented a prioritization level for referral, provincial wait times have not been reported by priority level. Factors that can influence decisions to treat or book a consultation should be considered when assessing an association between priority levels and wait times.

2.2.3. Factors impacting wait times

Several factors can impact WT1 and WT2, including an increase in demand for hip and knee replacement surgery,[9-25] hospital bed capacity,[97-101] patient preference,[70-72] age,[70,99] gender,[70,72,102] comorbid diseases,[70-72,97,102] or incomplete referral form status[73] can influence wait times for consultation and for surgery. Kathleen Morris, Vice President of Research and Analysis at the Canadian Institute for Health Information said that the increasing number of surgeries performed does not mean patients will have shorter wait times. Canada's aging population, and an increase in osteoarthritis or obesity can result in a growing demand for hip and knee replacement surgeries.[26]

Increase in demand. In Canada, the volume of demands for surgeries significantly increased from 13,746 to 21,472 cases for hip replacements and from 23,082 to 34,751 cases for knee replacements, respectively, between 2010 and 2018.[9] The percentage of patients receiving

surgeries within the national benchmark of 182 days gradually reduced from 84% in 2010 to 75% in 2018 for hip replacement, and from 80% in 2010 to 69% in 2018 for knee replacement.[12] In Newfoundland and Labrador, reports showed that the percentage meeting the benchmark of 182 days for the joint replacement surgeries dramatically rose from 75% in 2010 to 96% in 2014, but decreased to 88% in 2018 for hip replacement, and from 67% in 2010 to 92% in 2014, and dropped to 75% in 2018 for knee replacement.[12,13] Moreover, the Fraser Institute reports 2006-2018 illustrated that the median total wait time for Newfoundland patients climbed from 36.8 weeks in 2006 to 48.6 weeks in 2017,[11,14-25] but reduced to 31.2 weeks in 2019.[10]

Length of Stay. The operating room involving many factors such as the availability of healthcare professionals, supplies, medications, and bed space can impact how quickly patients have surgery.[97] The unavailability of hospital bed spaces for surgery may result in postponement or cancellation of elective surgeries.[98] Therefore, a decrease in the length of stay allows more patients to receive surgery.[99] The average length of stay (LOS) for hip and knee replacement patients decreased over the last decade. Nationally, patients with hip replacements spent an average of 9 days in hospital in 2004-2005,[100] compared to 3 days in 2017-2018.[101] Similarly, the average LOS for knee replacement decreased from 7 days in 2004-2005[100] to 3 days in 2017-2018.[101]

Newfoundland and Labrador was one of five provinces that had the longest length of stay for hip and knee replacements (Manitoba, Prince Edward Island, Newfoundland and Labrador, New Brunswick, and Quebec) in 2004-2005. The average LOS for hip replacement was about 11 days for males, and 13 days for females. Additionally, that figure for knee replacement was approximately 8 days for males, and 9 days for females.[100] However, in 2017-2018, the acute LOS for hospitalization for hip and knee replacement in the province was the same as the national LOS, at about 3 days.[101]

Patient preferences. Patients' willingness to change to the next available surgeon who has a shorter waiting time may affect their actual waiting times. Ferguson et al.[70] identified that choosing the next available surgeon would help reduce waiting times. However, only a small percentage of patients waiting for hip and knee replacement surgeries in Canada chose this option.[70] Moreover, patients would not consider changing to another surgeon with a shorter waiting time if they could not tolerate their pain because of their trust in specific surgeons, the reputation of the surgeons, and the recommendation of general physicians.[71,72]

Age. The risk of revision in patients under age 60 is higher than that in older people because their physical activities may put pressure on the prosthetic joints. Therefore, patients belonging to this younger age group tend to delay their surgeries.[70,99]

Gender. Although females have a higher prevalence of the arthroplasty surgery and have worse outcomes than males, women have higher resistance or unwillingness to consider arthroplasty surgeries.[70,72,102]

Comorbidities. Obesity is a high-risk factor for osteoarthritis. Osteoarthritis is the most common cause of total joint arthroplasty surgery, and a higher BMI may increase the risk of total joint replacement.[70-72,102] Other medical reasons can also cause delays in surgeries.[97]

Completed referral form. Incomplete referral forms may result in prolonged waiting time from referral to seeing a specialist. Fyie et al.[73] identified that fifty-four percent of new referrals were rejected, which prolonged wait time for consultation by 8-46 business days.

2.3. The role of SEM in improving timely access in healthcare services

In traditional models, each surgeon will receive referrals and manage their own queue. When a patient is referred to a surgeon whose appointment slots are not available, the patient has to wait until a slot is available. As a result, that patient cannot have an appointment with the next

available surgeon.[41] Therefore, SEMs have been implemented in healthcare services to avoid the disadvantages of the traditional models. In the SEM, multiple queues are consolidated into a single queue through a central intake system, and patients can meet the next available surgeon from a pool of participating surgeons.[47,48]

SEMs are being used to improve WT1 and non-urgent WT2. The SEMs have been implemented in gastroenterology,[103] ophthalmology,[104] and general elective surgery.[105-108] Moreover, the use of SEMs for orthopedic surgery has also been used to improve wait times for patients with hip and knee replacement.[47,48,51,55,86,109,110]

2.3.1. The SEMs in general surgeries

In the UK, National Health Service Hospitals implemented a SEM to manage waiting lists for both consultation and surgery in routine spinal surgery.[106] All new referrals from general physicians are pooled and allocated to the next available specialist. When specialists consider a patient for elective non-complex spinal surgery, they will indicate whether that patient needs to be under their care, or the patient will be put into a pooled waiting list for surgery. Leach et al.[106] demonstrate that the number of patients waiting more than 26 weeks was close to zero and those waiting more than 13 weeks was significantly reduced. Additionally, the mean wait time from MRI scan to outpatient review reduced from 185 days to 31 days, and the percentage of patients waiting more than 9 months for surgery fell to zero.[106]

Another SEM was implemented to improve access in hernia service.[108] Patients were triaged by a single surgeon at the clinic and referred to the next available consultant for consultation. Nurses would pre-assess patients and the Day Surgery Unit (DSU) surgeon would check and confirm the diagnosis. Sriram et al.[108] revealed that patients who were referred through

a SEM had a TW from referral to surgery of approximately 70 days, compared to 161 days in patients following the traditional pathway.

In Australia, a SEM by pooling elective surgery referrals for admission was implemented in the Western Sydney Health Area Service.[106] Singh et al.[107] revealed that the project doubled the number of surgical procedures, and about 57% of patients were discharged on the day of surgery. Additionally, waiting lists for procedures were terminated.[107]

In Canada, the Cardiac Ensuring Access and Speedy Evaluation (EASE) was implemented by an outpatient clinic that provides consultative services for the northern Alberta region.[105] Cardiac EASE includes a multidisciplinary clinic (cardiologists, nurse practitioners, and doctoral-trained pharmacists) and a central triage service. From 2004 to 2006, wait times reduced from 71 days to 39 days for consultation, and from 120 days to 51 days for diagnosis. The number of new referrals grew from 1512 in 2002 to 2574 in 2006. In contrast, patients who were referred through traditional pathways did not improve their WT1.[105]

Similarly, gastroenterologists in Calgary developed a central referral intake to manage wait times in 2005, and the University of Alberta Hospital adopted that model in 2008.[103] These SEMs include pooling a list of physicians and triaging a patient in accordance with the best evidence-based guidelines. Over 50% of referrals were triaged by nurses, while more complex cases were triaged by rotating gastroenterologists. Novak et al.[103] showed that urgent patients had to wait less than two weeks for acute consultations, and about four weeks for an urgent slot, compared to more than one month and nine weeks, respectively, before SEMs were implemented. However, the number of non-urgent referrals continued to increase, and non-urgent patients had to wait between 18 and 24 months for consultation.

2.3.2. The SEMs in orthopedic surgery

In Australia, the Orthopedic Unit of the Repatriation General Hospital in Adelaide implemented a SEM to improve timely access for hip and knee replacement surgery in 2006. Key elements that were designed in this SEM include improving referral and triage systems, establishing additional assessment clinics, and extending the roles of physiotherapists in the triaging process.[85] Doerr et al.[85] showed that after a four-year implementation, the SEM shortened wait times from 8 to 3 months for consultations with surgeons, and from 18 to 8 months for surgery. Additionally, the length of stay reduced from 6.3 to 5.3 days for hip replacement, and 5.8 days to 5.3 days for knee replacement.[86]

In Canada, SEMs have been implemented by health regions in Alberta,[49-51] British Columbia,[52,53] Ontario,[55] Manitoba,[46,48,54] Nova Scotia,[56,57] and Newfoundland and Labrador.[58]

The SEM improves timely access in hip and knee replacement surgery. In Alberta, a single intake model was launched at each of three regional health authorities in 2005. The evaluation report of the Alberta Hip and Knee Joint Replacement (2006) showed that wait times in the new approach were approximately 21 days for consultation and 7.5 weeks for surgery, compared with approximately 145 days for consultation, and 58 weeks for surgery under the traditional care.[49] In British Columbia, the OASIS (Osteoarthritis Service Integration System),[52] a single-entry point for referrals, was established at three clinics in Vancouver, the North Shore and Richmond in 2006. According to a report from Vancouver Coastal Health (2008),[52] waitlists reduced by 30%, and the percentage of patients waiting more than 24 weeks decreased by 63%. Another SEM was implemented at the Fraser Health Authority in 2017.[53] The SEM improves timely access to assessment. The average TW from referral to surgery decreased from 278 days to 106 days for hip replacement, and 320 days to 106 days for knee replacement between 2015 and 2019.[53] In

Manitoba, the Winnipeg Regional Health Authority established a central intake for hip and knee joint replacement in 2012. Damani et al.[48] revealed that WT2 and TW after implementing the Winnipeg Central Intake Service (WCIS) were 28.1 and 41.8 weeks for hip replacement, and 31.4 and 45.4 weeks for knee replacement. Before WCIS implementation, WT2 and TW had been approximately 31.1 and 43 weeks for hip, and 37.9 weeks and 56 weeks for knee.[48] Additionally, the percentage of patients receiving knee replacement surgery within the national benchmark of 182 days increased 5.9% (before WCIS: 43.2% vs. after WCIS: 49.1%). In Ontario, the Hip and Knee Replacement program was implemented by the Toronto Central Local Health Integration Network (TC LHIN) in May 2007.[55] The program developed a single wait list and standardized referral form that would be sent to a single central intake center within TC LHIN. Referrals were screened and triaged by advanced practice physiotherapists to determine urgency and followed by a booked consultation.[55] MacLeod et al.[55] demonstrated that 90% of patients within TC LHIN waited for their hip and knee replacement surgery under 115 days, and the WT1 in this health region were less than 100 days. In Nova Scotia, one of the hip and knee replacement action plans in 2018 was to create and extend the Orthopedic Assessment Clinics (OACs). All referrals from physicians would be sent to OACs. After referrals are received, patients would be booked for an appointment with the OAC team for assessment. If a patient is a good candidate for surgery, the patient will be booked for an appointment for consultation with a surgeon by the OCA team. According to the Joint Replacement Indicator Report (2018),[57] 45% of patients had their hip and knee replacement surgery within the national benchmark of 182 days. Additionally, 37% of Nova Scotians received their surgeries within the wait time for their priority level.[111] However, Nova Scotia does not have provincially standardized triage categories with corresponding wait times for each level of triage urgency for total hip and knee replacement surgery, and a priority score is determined by individual surgeons. For all total hip and knee

replacement surgeries, the target is to assess patients by a nurse/physiotherapist team within 30 days of receipt of referral, by the surgeon within 90 days of receipt of referral, and to have their surgery completed within 6 months from the decision to have surgery.

The SEM may reduce the number of referrals that were not suitable for surgery before seeing a surgeon for consultation. In Alberta, 28% of referrals received by the central intake and assessment clinics were suitable for non-surgery treatment at that time.[49] In British Columbia, up to 47% of patients who were referred to OASIS for surgical assessment were suitable for non-surgical management from 2012 to 2015.[112] In Ontario, Robarts et al.[113] revealed that a single central intake at the Sunnybrook health science center optimized capacity because about 30% of patients did not need surgeries or chose conservative treatment. In Winnipeg, after the WCIS was implemented, 8% of referrals were not sent to surgeon offices because those referrals were not suitable for surgery.[48]

Moreover, the SEM might improve efficiency in using healthcare resources, length of stay, length of time in operating room, and costs. According to the Alberta Project report (2006),[49] patients through a SEM had a surgery time of 109 minutes and length of stay of 4.7 days, compared to 119 minutes and 6 days in the current approach. Additionally, hospital costs, including the cost of the operating room, the prosthesis and in-patient stay reduced by 15% in the SEM.[49] Similarly, in the OASIS program, efficiency in the operating room increased by 20-25%. In terms of length of stay, the OASIS program reduced the average length of stay to 4 days for hip replacement surgery, and to 3 days for knee replacement surgery.[52]

In Newfoundland and Labrador, a SEM was implemented in the Eastern Health Region in 2011[58] and then was implemented in the Western Health Region in 2013[61] in order to improve wait time and referral management. In the Eastern Health Region, the OCI team developed their priority tool for triage assessment. For routine priority classification, patients placed in priority 4

will be considered as not suitable for consultation at triage assessment, but they can have an appointment for consultation if they do not respond to their conservative treatment. In contrast, patients in priority 1, 2, and 3 will be booked for an appointment with a surgeon for consultation within 45 days, 90 days, and 6 months to under 12 months, respectively, from receipt of complete referral, respectively.[60] Overall, they showed improvement in wait times by priority. According to Eastern Health's annual performance reports (2011-2012, 2012-2013, 2013-2014),[62-64] the median WT1 of priority 1 and 2 reduced from 95 days to 47 days, and that of priority 3 and 4 dropped from 182 days to 123 days.[62-64] Additionally, referrals which were suitable for conservative management accounted for 23% of the total referrals received in the OCI clinic.[114]

2.4. Gaps in the literature

Reporting wait times are not consistent across provinces. Most provinces report WT2, but not WT1, apart from Ontario, Nova Scotia, and Alberta. Moreover, factors including an increase in demand, length of stay, patient preferences, age, gender, comorbidities, and completed referral forms can cause long TW from referral to surgery, but TW has not been reported along these parameters on provincial wait time systems.

There are challenges in the use of priority tools for managing wait times. First, Taylor et al.[115] showed that patients with low priority may never reach the top of the waiting list when surgeons see a high volume of patients with high priority. In fact, a discrete event simulation model was developed to examine the effects of four strategies on waiting time. Cipriano et al.[109] showed that after five years of implementing strict clinical prioritization, the number of more severe scoring patients receiving surgery within maximum acceptable waiting times increased while that figure in low-priority patients receiving surgery within 6 months decreased. Second, the decision to treat is an agreement between surgeon and patient and depends on several factors such as patient's

preference for surgeons,[70-72] willingness to undergo surgery, age, and gender.[70,72,102] However, there is a lack of studies about the use of priority classifications in clinical practice.

The SEM in the Eastern Health region in Newfoundland and Labrador has some gaps. First, the OCI clinic at Eastern Health has not tracked WT2 by priority yet. For this reason, little is known about whether patients assigned a higher priority level at the OCI clinic may receive surgeries before those with lower priority levels. Second, many factors may influence wait times for hip and knee replacement surgery, but TW has not been examined carefully. Although the Fraser Institute estimated the TW from referral to surgery, these medians of TW were based on surveys that had low response rates.

2.5. Summary

Research is needed to measure how long patients at each priority in a SEM wait for a consultation with a surgeon and for their surgery, what percentage of patients may receive their consultation and surgery within the targeted wait time, and the TW from referral to surgery. This evidence will ensure that the SEM can help patients with higher priority receive consultation and surgery earlier, but it can also help patients with lower priority to access healthcare services within the maximum acceptable wait time. Additionally, an estimated TW will provide healthcare providers with a better understanding of influential factors impacting the whole pathway of hip and knee replacement surgery.

However, because of a lack of linkage from OCI database to the hospital database, waiting time for consultation from the SEM at Eastern Health were not reported until 2015, and not much is known about how long patients whose referrals were sent to the OCI waited to receive their surgery. This study will fill these gaps in knowledge by using linked data from the OCI and Total Joint Assessment Center (TJAC) databases.

Chapter 3. Data and method

This study aims to evaluate and provide evidence regarding improvements in wait times for hip and knee replacement surgery after the implementation of the SEM in the Eastern Health region in 2011. A secondary data analysis is conducted in all adult patients diagnosed with a primary problem regarding their hip(s) or knee(s), and who were referred to the Orthopedic Central Intake (OCI) clinic in the Eastern Health region for an arthroplasty assessment between 2011-2019. This chapter contains three sections: Section 3.1 describes data in the study, Section 3.2 describes the statistical method employed, and Section 3.3 illustrates ethical considerations in the study.

3.1. Data

3.1.1. Data sources

The data used in this study came from two main databases in the Eastern Health region: The Orthopedic Central Intake (OCI) database and the Total Joint Assessment Center (TJAC) database. The OCI database is comprised of health insurance plan numbers, patient's demography, and information regarding patient administration referral. The patient administration referral information includes: the date the patient is referred; the date the referral is received; the first date the referral is screened; the date the screening is completed; the date of the first available appointment with a surgeon; diagnosis; patient's preference for surgeon - a specific surgeon versus the next available surgeon; the surgeons' names; and priority level. The TJAC database contains patient demography, the date of the decision to accept surgery, the date a surgery is completed, and surgeons' names.

The Orthopedic Central Intake clinic extracted variables from the OCI database and the TJAC database. The OCI clinic used Medical Care Plan (MCP) numbers to link between the two

databases. Finally, they assigned study identification numbers to patients in the cohort linkage and then removed MCP numbers and patient names. The Information Security and Privacy Office at Eastern Health screened the de-identified data before its release.

3.1.2. Variables

Variables from the Orthopedic Central Intake Clinic database

Primary affected joints. A family doctor sends an Orthopedic Central Intake Patient Referral Form to the OCI clinic for an assessment of joint arthroplasty. Primary affected joints - hip and knee - was treated as a binary variable.

Diagnosis. To assess the factors impacting wait times, hip or knee replacement surgery due to osteoarthritis or other arthritis disorders were categorized as a binary variable.

Date of birth. Only adults were included in the study. Therefore, individuals had to be aged 18 or older at the time they were referred to the OCI clinic to be included.

Age was categorized as a binary variable: < 65 year-of-age and ≥ 65 year-of-age. We chose the age threshold at 65 because of two main reasons. First, from a methodological viewpoint, one of the most practical ways of defining a senior is choosing the age marker of 65. Second, from a conceptual viewpoint, defining seniors as individuals aged 65 and older is advantageous because most people at this age are considered 'senior citizens' and receive full pension benefits in Canada.[116]

Patient's preference. The SEM provides patients with two choices: the 'next available surgeon' or 'a specific surgeon' on the Orthopedic Central Intake Patient Referral form. Patients may choose the next available surgeon with a shorter waiting list, but they may wish to meet with a specific surgeon, no matter the length of the surgeon's waiting list. To assess influential factors

on wait time, the patient's preference - the next available surgeon and a specific surgeon - was treated as a binary variable.

The date on the referral form. In the Eastern Health region, WT1 starts when a family doctor refers a patient to the OCI clinic. To measure the starting point of WT1, the referral date to the OCI clinic was used. Additionally, this was also used to create the year of referral variable to examine the demand of hip and knee replacement associated with wait times. Year of referral was categorized as categorical variable: 2011-2013, 2014-2016, and 2017-2019.

The date of the first consultation. WT1 end on the date of the first consultation. The date of the first consultation with an orthopedic surgeon was utilized to measure the ending point of WT1.

Clerical incomplete date. To access incomplete referral form statuses, which might have an impact on wait times, incomplete clerical dates were examined. Based on this variable, it is possible to know whether a referral form was or was not completed. The incomplete referral form was treated as a binary variable, as either 'complete' or 'incomplete.'

Priority levels. To measure wait times by priority levels, different priority levels were used. According to OCI referral prioritization guidelines (2012),[60] a routine priority classification has four categories: priority 1 – the highest priority routine level in which patients are at the end stage pathology or complex musculoskeletal issue, high level of dysfunction, and conservative treatment options failed; priority 2 – moderate priority routine level in which patients are at moderate to end stage pathology or complex musculoskeletal issue, moderate to high functional impairment despite best conservative management or unresponsive to therapy over several weeks; priority 3 – low priority routine level in which patients are at early to moderate stage pathology, moderate functional impairment, minimal evidence of conservative management trialed or currently managing with conservative interventions; and priority 4 – patients are at early stage disease, minimal symptoms or functional impairment, minimal evidence of

conservative treatment and probably unsuitable for surgery. Priority levels were treated as a categorical variable, cited as priority 1, priority 2, priority 3, and priority 4.

Variables from the Total Joint Assessment Center database

Date of a decision to treat. To measure a starting point of WT2, the date of a decision to begin treatment was used in the TJAC database. Wait time for surgery began on the date when a surgeon and a patient decide to have surgery.

Date of surgery. The date of surgery was used to measure the endpoint of WT2. The date of the surgery was the date when a patient received a hip or knee replacement surgery.

3.1.3. Sample selection

Table 3.1 presents inclusion and exclusion criteria for the study. We included adult patients aged 18 years and older that were referred to Orthopedic Central Intake Clinic at Eastern Health for a total hip and knee arthroplasty assessment between 2011 and 2019. Age 18 is considered as one of the milestones transited to adulthood.[117] Patients aged 18 years or older also access to the adult hospitalist services.[118]

Patients were excluded if they have joint disorders not involving in hip or knee (shoulder, neck, or ankle), or if they were referred for other reasons, including obtaining partial hip or knee replacements and/or revisions, or if they had urgent referrals booked directly through the hospital. We excluded 'one referral to multiple surgeries' cases where patients used to undergo a hip or knee replacement surgery at the hospital before being referred to OCI for a second hip or knee replacement surgery assessment, or where patients had future or revision surgeries without going through the OCI clinic. We also excluded 'multiple referrals to one surgery' cases where patients had both left and right hip or knee replacement assessments, but only one-side hip or knee replacements were performed. Finally, we excluded 'multiple referrals to multiple surgeries'

cases. These cases were excluded because the data linkage strategy used by OCI (using MCP numbers or date of birth to link the OCI database with the TJAC database), did not allow us to determine which pair of referrals and surgeries was a true match.

Table 3.1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
• Patients aged 18 and older • Total hip and knee replacement surgery	• Joint disorders not involving in hip or knee (shoulder, neck, ankle) • Partial hip or knee replacement • Hip and knee replacement revision • Referrals without being linked to TJAC database • Urgent referrals booked directly through the hospital • 'One referral to multiple surgeries' cases • 'Multiple referrals to one surgery' cases • 'Multiple referrals to multiple surgery' cases

3.2. Statistical analysis

We used the SAS® Foundation 9.4 software package to analyze data.

3.2.1. Descriptive analysis.

First, descriptions of two populations: hip replacement and knee replacement, were conducted. We used frequencies and percentages to describe: age group: < 65 years of age and ≥ 65 years of age; diagnosis - osteoarthritis and others; priority levels - P1, P2, P3, and P4; initial referral form status - incomplete referral form and completed referral form; patient's preference for surgeon - the next available surgeon and a specific surgeon; and year of referral - 2011-2013, 2014-2016, and 2017-2019.

Second, comparisons of the percentage of patients with hip replacement and knee replacement receiving a consultation within a benchmark of 90 days recommended by COA across priority levels were performed by using the Chi-Square test or Fisher's Exact. Similarly, we used the Chi-Square test or Fisher's Exact to examine the percentage of patients with hip replacement

and knee replacement having a surgery within a benchmark of 182 days across priority levels. Fisher's Exact test was used when more than 25% of cells had expected frequencies < 5.

Third, we used a descriptive analysis to examine the percentage of patients in each priority group that had a consultation within an acceptable timeframe according to the OCI priority classification of Eastern Health.

3.2.2. Survival analysis

Survival analysis, known as the 'time-to-event' analysis or 'failure-time' analysis, has been applied in the modeling of wait times because of certain advantages in analyzing wait time data. First, survival analysis examines individually recorded data that are used to measure wait times.[119] Second, survival analysis allows the random error ε to follow alternative distributions besides the normal distribution.[120,121] Lastly, survival analysis can handle censored observations.[120,121]

WT1 was measured as the duration from the date on the referral form to the date of the first consultation, WT2 was measured as the duration from the date of the decision to treat to the date of surgery, and TW was measured as the duration from the date of referral to the date of surgery. In this study, having the first appointment with a surgeon or surgery performed was an 'event,' while remaining on the waiting list was considered 'survival.'

Kaplan Meier (KM) estimators were used to estimate median WT1, WT2, and TW. A KM estimator, also known as the product-limit estimator, is the most common method for estimating survivor functions. The survivor function $S(t)$ is defined as the probability that event time is greater than t, where t is any positive number.[121] In this study, the KM estimator $S(t)$ is the proportion of patients at each priority level with WT1, WT2, or TW, greater than t. A log-rank test was used to identify differences in the survivor function among priority groups. The log-rank test was also used to compare the TW between hip and knee replacement in each priority group.

Additionally, a Cox proportional hazard regression model was used in order to control and assess the effects of variables, including age group, patient's preference for surgeon, incomplete referral status, primary affected joint, diagnosis, year of the referral, and priority on wait times. The Cox proportional hazard regression model is semi-parametric because the hazard function is non-parametric, while functional forms of covariates are parametric.

$$\log h_i(t) = \alpha(t) + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 \qquad (1)$$

where: t = wait time (in days)

X_1 = age group

X_2 = diagnosis

X_3 = patient's preference for surgeon

X_4 = initial referral status

X_5 = year of referral

X_6 = priority

We conducted a multiple Cox-regression analysis by using a stepwise selection procedure. Variables included in the Cox regression models for WT1 and TW were age group, diagnosis, patient's preference for surgeon, initial referral status, year of referral, and priority. Initial referral status was assumed to not impact WT2. In fact, the initial referral form was assessed by the OCI clinic for triaging patients and would be re-sent to physicians if it was not complete. As a result, the initial referral status might prolong WT1, and probably increase a TW from referral to surgery. Therefore, we did not include initial referral status in the Cox regression model for WT2.

Choosing a *significance level for entry (sle)* and a *significance level for stay (sls)* is important in the stepwise selection procedure. Hosmer & Lemeshow (2000) suggested that the value for *sle* should be between 0.15 and 0.20.[122] In this study, the value we chose for *sle* was

0.20. There is not enough information on a good value for *sls*, so we chose a default value of *sls*=0.15 for the stepwise selection procedure.[123]

The next step was to assess the proportional hazard assumption by using score process plots and the corresponding proportional hazards tests. With any covariate violating the assumption, we added their interaction with time to the model. Adding the interaction between variables and time to the model, the hazard then become:

$$h_x(t) = h_o(t)exp(\beta_0 x + \beta_1 x*WT) \quad (2)$$

The method that adds the model interaction of covariates with time is considered as a potential way to solve those violation issues.[124] Then, we continued to use the stepwise selection procedure with *sle*=0.2 and *sls*=0.15 in order to produce the final extend Cox regression models.

3.2.3. Logistic regression analysis

Logistic regression model was used to evaluate the association between receiving a consultation within a benchmark of 90 days (yes/no) and influential factors; and the association between receiving a surgery within a benchmark of 182 days (yes/no) and influential factors. Because we would like to examine all potential factors impacting receiving a consultation and surgery within the benchmarks, we chose the direct approach that enters all independent variables into the model at the same time without assumptions about the order or relative importance of the variables.[125] Moreover, the assumptions of logistic regression for multiple logistic regression model must be met. We checked the absence of multicollinearity assumption by exploring the Pearson Correlation Matrix and examining the value of variance Inflation Factor and tolerance before doing the analysis. If any of variables has a high correlation about 0.8 or higher with other variable, these variables will have a high correlation. Additionally, if none of the values of the

Variance Inflation Factor is below 0.1, and no value of the tolerance is above 10, a lack of multicollinearity is indicated.[126]

The equation for the multiple logistic regression model of receiving consultation within 90 days is as follows:

$$Logit\ (Odds) = log\ (\frac{p}{1-p}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 \qquad (3)$$

Where

p is the probability of having a consultation within 90 days

X_1: age group

X_2: diagnosis

X_3: patient's preference for surgeon

X_4: incomplete referral status

X_5: year of referral

X_6: priority

The equation for the multiple logistic regression model of receiving surgery within 182 days is as following

$$Logit\ (Odds) = log\ (\frac{p}{1-p}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 \qquad (4)$$

Where

p is the probability of having a surgery within 182 days

X_1: age group

X_2: diagnosis

X_3: patient's preference for surgeon

X_4: year of referral

X_5: priority

For each regression, we conducted a univariate logistic regression model to examine influential factors on receiving a consultation or a surgery within benchmarks. We then conducted a multiple logistic regression analysis to include covariates. We used the Hosmer and Lemeshow Goodness-of-fit test to check the goodness of fit of the first model containing all covariates, including the age group, diagnosis, patient's preference for the surgeon, year of referral, priority, and initial referral status (logistic regression model for receiving consultation with 90 days). Second, if the test of hypothesis for goodness-of-fit was violated, we would add their interactions into the model, and then we continued to check the goodness-of-fit of the new models. Finally, odd ratios and the ROC (Receiver Operating Characteristic) curves were reported. The ROC is used to determine the model's ability to discriminate between those patients who received consultation or surgery within benchmarks versus those who did not.

3.3. Ethical considerations

Our study (HREB # 2019.168 – Wait times in hip and knee replacement: Single entry model and prioritization) was reviewed by the Health Research Ethics Board and received approval on August 15, 2019. An initial amendment was approved on May 8, 2020, a second amendment was approved on July 16, 2020, and a third amendment was approved on October 27, 2020. The amendments were related to sample sizes and modified data access procedures related to COVID19 closures. The third amendment was related to add research objectives regarding factors associated with the receiving consultation and surgery within benchmarks. Additionally, a HREB personnel change form was approved on November 12, 2020.

This study was reviewed by the Research Proposals Approval Committee (RPAC) of Eastern Health and granted full approval on September 10, 2019.

Chapter 4. Results

This chapter include three sections: Section 4.1 describe results of data linkage hip and knee surgery through the SEM in Eastern Health from 2011-2019, Section 4.2 illustrates an evaluation for improving timely access to care for hip and knee replacement through the SEM, and Section 4.3 showed factors impacting the receiving consultation and surgery within established benchmarks for hip and knee replacement in the SEM.

4.1. Results of data linkage

Figure 4.1 shows the process of selecting our study sample. There was a total of 25,651 cases in the OCI database between 2011 and 2019. After excluding nine duplications, seven patients with hip and knee revision, the Orthopedic Central Intake clinic received 25,635 referrals for hip or knee replacement assessment. A total of 25,635 referrals were linked to 5,157 surgeries in the TJAC database. We excluded 20,478 referrals that were not linked to the TJAC database.

We excluded 1,024 referrals were excluded in instances where one referral was linked to multiple surgeries, 1,318 referrals were excluded in instances where multiple referrals were linked to one surgery, and 338 referrals were excluded in instances where multiple referrals were linked to multiple surgeries. Of 2477 ‘one-to-one’ referrals, we excluded 134 referrals with a negative duration (wait time less than 0), and 376 referrals with no matched to surgeon. Duration is defined as a length of time from a date of the first consultation to a date of decision to treat. A case is considered a ‘not-matched surgeon’ case when both the consultation and the surgery were performed by different surgeons. In contrast, a case is a ‘matched surgeon’ case when both the consultation and the surgery were conducted by the same surgeon. In the OCI clinic, the pooling of surgeons is for consultation, not for surgery. This means that if a patient is assessed by a surgeon, the surgery will be performed by that surgeon. Cases with negative duration were

caused by a number of reasons. First, transposition errors occurred when the information was entered in the wrong order between 'Decision to Treat Date Booking' and 'Date First Available'. Second, there were some patients who had had previous hip or knee replacement surgeries before their latter referrals were referred to the OCI for assessment. Although these second referrals were not suitable for surgery after consultation, the latter consultation was matched to the previous surgery.

We included 1967 patients aged 18 or older who were referred to the OCI Clinic at Eastern Health for a total hip and knee replacement assessment between 2011 and 2019. All of 1967 referrals were linked to 1967 individual surgeries (one referral to one surgery) in the TJAC database. Among the 1,967 patients with joint replacement surgery included in the analysis, there were 808 (41.08%) patients with hip replacement surgery and 1,159 (58.92%) patients with knee replacement surgery.

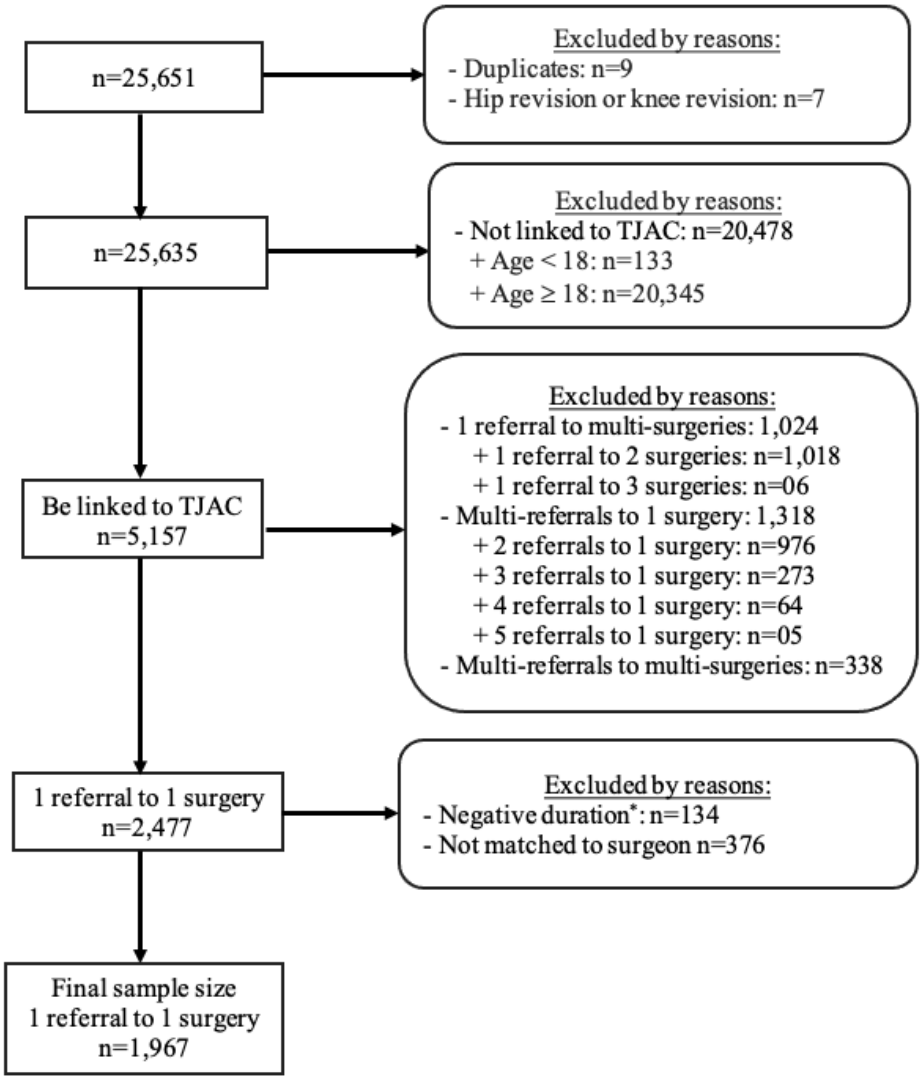

Figure 4.1. A process of the study sample

*duration is a length of time from a date of the first consultation to a date of decision to treat

4.2. Descriptions of hip and knee replacement surgery through the SEM

Description of characteristic of participants with hip replacement

Table 4.1 presents the characteristics of patients, the percentage of patients receiving consultation and surgery within established benchmarks. Patients aged 65 or older accounted for 55.07% (n=445), while patients under 65 took up 44.93% (n=363) of the sample. Hip

osteoarthritis accounted for 88.61% (n=716), while other arthritis disorders took up 11.39% (n=92). When assigned priority for consultation, 66.46% (n=537) of patients were assigned a priority 2, 24.13% (n=195) of patients were assigned a priority 1, 9.16% (n=74) of patients were assigned a priority 3, and 0.25% (n=2) patients were assigned a priority 4. Only 3.96% (n=32) of initial referrals were not complete on arrival at the Orthopedic Central Intake Clinic. 72.03% (n=582) of patients were referred to the next available surgeon for a consultation, whereas 27.97% (n=226) of patients requested a specific surgeon. In terms of percentages of referrals referred to the OCI clinic, 29.58% (n=239) were referred in 2011-2013, 37.87% (n=306) were referred in 2014-2016, and 32.55% (n=263) were referred in 2017-2019.

The percentage of patients receiving consultation and surgery within the benchmarks

There was an association between priority levels and the proportion of patients receiving a consultation within the maximum acceptable wait time of 90 days ($p<.0001$). The largest proportion of patients receiving a consultation within 90 days were 83.08% (n=162) in priority 1, followed by 66.48% (n=357) in priority 2. Only 9.46% (n=7) of patients with priority 3 had a consultation within 90 days, and none of patients within priority 4 received a consultation within this maximum acceptable wait time. In contrast, the highest percentage of patients having hip replacement surgery within 182 days were 81.08% (n=60) in priority 3, followed by 63.08% (n=123) in priority 1, and then 52.33% (n=281) in priority 2. The difference in the proportion of patients receiving surgeries within a benchmark of 182 days among priority levels was significant, with $p<.0001$.

Table 4.1. Descriptive characteristics for hip replacement participants from 2011-2019 (n=808)

Variables	n (%)	Wait time for consultation			Wait time for surgery		
		≤ 90 days n (%)	> 90 days n (%)	p-value[a]	≤ 182 days n (%)	> 182 days n (%)	p-value[a]
Age group				0.0102			0.6122
< 65	363 (44.93 %)	219 (41.63 %)	144 (51.06 %)		212 (45.69 %)	151 (43.90 %)	
≥ 65	445 (55.07 %)	307 (58.37 %)	138 (48.94 %)		252 (54.31 %)	193 (56.10 %)	
Diagnosis[b]				0.6604			0.1084
Osteoarthritis	716 (88.61%)	468 (88.97 %)	248 (87.94 %)		404 (87.07 %)	312 (90.70 %)	
Others	92 (11.39 %)	58 (11.03 %)	34 (12.06 %)		60 (12.93 %)	32 (9.30 %)	
Priority				<.0001			<.0001
P1	195 (24.13%)	162 (30.80 %)	33 (11.70 %)		123 (26.51 %)	72 (20.93 %)	
P2	537 (66.46%)	357 (67.87 %)	180 (63.83 %)		281 (60.56 %)	256 (74.42 %)	
P3	74 (9.16%)	7 (1.33 %)	67 (23.76 %)		60 (12.93 %)	14 (4.07 %)	
P4	2 (0.25%)	0 (0.00 %)	2 (100 %)		0 (0.00 %)	2 (0.58 %)	
Initial referral[c]				0.0097			0.6156
Incomplete	32 (3.96 %)	14 (2.66 %)	18 (6.38 %)		17 (3.66 %)	15 (4.36 %)	
Complete	776 (96.04 %)	512 (97.34 %)	264 (93.62 %)		447 (96.34 %)	329 (95.64 %)	
Patient's preference for surgeon				0.3995			0.0242
Next available	582 (72.03 %)	384 (73.00 %)	198 (70.21 %)		320 (68.97 %)	262 (76.16 %)	
Specific surgeon	226 (27.97 %)	142 (27.00 %)	84 (29.79 %)		144 (31.03 %)	82 (23.84 %)	
Year of referral[d]				<.0001			<.0001
2011-2013	239 (29.58 %)	104 (19.77 %)	135 (47.87 %)		165 (35.56 %)	74 (21.51 %)	
2014-2016	306 (37.87 %)	212 (40.30 %)	94 (33.33 %)		137 (29.53 %)	169 (49.13 %)	
2017-2019	263 (32.55 %)	210 (39.92 %)	53 (18.79 %)		162 (34.91 %)	101 (29.36 %)	

[a] Significance level p-value <0.05 for the Chi-Square test or of the Fisher's Exact test that is used when > 25% of cells have expected frequencies < 5

[b] A total hip replacement surgery for osteoarthritis or other hip arthritis disorders

[c] A standard referral form status when it was sent to the OCI at the first time by family doctors.

[d] The year when a patient was referred to the OCI for hip or knee replacement assessment

Description of characteristic of participants with knee replacement

Table 4.2 presents characteristics and the percentage of patients receiving consultation and surgery within the benchmarks. 48.32% (n=560) of patients was under 65, and 51.68% (n=599) of patients was 65 or older. Knee osteoarthritis made up 88.61% (n=1027) of patients, compared to 11.39% (n=132) for other causes. 65.06% (n=754) of patients were assigned a priority 2, and 24.42 % (n=283) of patients were assigned a priority 3. Patients with priority 1 and priority 4 accounted for a smaller proportion, with 10.01% (n=116) and 0.52% (n=6), respectively. 94.13% (n=1091) of initial referrals were completed whereas incomplete initial referrals made up only 5.87% (n=68) of the sample. The percentage of patients choosing the next available surgeon was almost double those requesting a specific surgeon, 66.95% (n=776) and 33.05% (n=383), respectively. The highest percentage of referrals sent to the OCI clinic was 40.81% (n=473) in 2014-2016, followed by 34.17% (n=396) in 2011-2013, and then 25.02% (n=290) in 2017-2019.

The percentage of patients receiving consultation and surgery within the benchmarks

The highest percentage of patients receiving consultation within 90 days was 73.28% (n=85) in priority 1, followed by 60.61% (n=457) in priority 2, and then 3.89% (n=11) in priority 3. None of patients with priority 4 had a consultation within 90 days. The association between the proportion of patients receiving a consultation within 90 days and priority levels was significant ($p<.0001$). Regarding having surgery within 182 days, 50.86% (n=59) of patients with priority 1 and 50% (n=3) of patients with priority 4 had surgeries within 182 days, while 45.23% (n=128) of patients with priority 3 and 41.78% (n=315) of patients with priority 2 receiving their knee replacement surgery within 182 days. However, a difference in the proportion of patients having surgeries within 182 days among priority levels was not significant ($p=0.2711$).

Table 4.2. Descriptive characteristics for knee replacement participants from 2011-2019 (n=1159)

Variable	n (%)	Wait time for consultation (WT1)			Wait time for surgery (WT2)		
		≤ 90 days n (%)	> 90 days n (%)	p-value[a]	≤ 182 days n (%)	> 182 days n (%)	p-value[a]
Age group				0.0063			0.1232
< 65	560 (48.32%)	244 (44.12 %)	316 (52.15 %)		231 (45.74 %)	329 (50.31 %)	
≥ 65	599 (51.68%)	309 (55.88 %)	290 (47.85 %)		274 (54.26 %)	325 (49.69 %)	
Diagnosis[b]				0.1962			0.1628
Osteoarthritis	1027 (88.61%)	497 (89.87 %)	530 (87.46 %)		440 (87.13 %)	587 (89.76 %)	
Others	132 (11.39%)	56 (10.13 %)	76 (12.54 %)		65 (12.87 %)	67 (10.24 %)	
Priority				<.0001			0.2711
P1	116 (10.01 %)	85 (15.37 %)	31 (5.12 %)		59 (11.68 %)	57 (8.72 %)	
P2	754 (65.06 %)	457 (82.64 %)	297 (49.01 %)		315 (62.38 %)	439 (67.13 %)	
P3	283 (24.42 %)	11 (1.99 %)	272 (44.88 %)		128 (25.35 %)	155 (23.70 %)	
P4	6 (0.52 %)	0 (0.00 %)	6 (0.99 %)		3 (0.59 %)	3 (0.46 %)	
Initial referral[c]				0.0181			0.0152
Incomplete	68 (5.87 %)	23 (4.16 %)	45 (7.43 %)		20 (3.96 %)	48 (7.34 %)	
Complete	1091 (94.13 %)	530 (95.84 %)	561 (92.57 %)		485 (96.04 %)	606 (92.66 %)	
Patient's preference for surgeon				0.7317			0.0078
Specific surgeon	383 (33.05 %)	180 (32.55 %)	203 (33.50 %)		188 (37.23 %)	195 (29.82 %)	
Next available	776 (66.95 %)	373 (67.45 %)	403 (66.50 %)		317 (62.77 %)	459 (70.18 %)	
Year of referral[d]				<.0001			<.0001
2011-2013	396 (34.17 %)	113 (20.43 %)	283 (46.70 %)		198 (39.21 %)	198 (30.28 %)	
2014-2016	473 (40.81 %)	256 (46.29 %)	217 (35.81 %)		154 (30.50 %)	319 (48.78 %)	
2017-2019	290 (25.02 %)	184 (33.27 %)	106 (17.49 %)		153 (30.30 %)	137 (20.95 %)	

[a] Significance level p-value <0.05 for the Chi-Square test or of the Fisher's Exact test that is used when > 25% of cells have expected frequencies < 5

[b] A total knee replacement surgery for osteoarthritis or other knee arthritis disorders

[c] A standard referral form status when it was sent to the OCI at the first time by family doctors.

[d] The year when a patient was referred to the OCI for hip or knee replacement assessment

The percentage of patients having a consultation within an acceptable timeframe according to OCI priority classification of Eastern Health in each priority group

Table 4.3 showed the percentage of patients having a consultation within an acceptable timeframe by priority levels according to the OCI priority classification. According to the OCI priority classification of Eastern Health, patients in priority 1, 2, and 3 will be booked for an appointment with a surgeon for consultation within 45 days, 90 days, and 6 months to under 12 months, respectively, from receipt of complete referral, respectively.[54] We chose the WT1 threshold at 182 days (6 months) for patients with priority 3 to examine the percentage of patients with priority 3 having consultation within this acceptable timeframe. In contrast, patients assigned in priority 4 will be considered as not suitable for consultation at triage assessment, but they can have an appointment for consultation if they do not respond to their conservative treatment.[54]

In the hip replacement surgery group, 47.69 % (n=93) of patients with priority 1 had a consultation with a surgeon within 45 days, 66.48 % (n=357) of patients with priority 2 had a consultation within 90 days, and 41.89 % (n=31) patients with priority 3 met a surgeon for a consultation within 182 days. Similarly, in the knee replacement surgery group, 37.07 % (n=43) of patients with priority 1 had a consultation within 45 days, 60.61% (n=457) of patients with priority 2 received a consultation within 90 days, while 40.99% (n=116) of patients with priority 3 had a consultation within 182 days. Only 16.67 % (n=1) of patients with priority 4 met a surgeon for a consultation within 182 days**.**

Table 4.3. The percentage of patients with hip replacement and knee replacement having a consultation within an acceptable timeframe according to OCI priority classification

Priority	Within an acceptable timeframe of the OCI priority classification			
	n (%)	Within 45 days n (%)	Within 90 days n (%)	Within 182 days n (%)
Hip replacement surgery (n=808)				
1	195 (24.13%)	93 (47.69 %)	162 (83.08 %)	193 (98.97 %)
2	537 (66.46%)	71 (13.22 %)	357 (66.48 %)	534 (99.44 %)
3	74 (9.16%)	2 (2.70 %)	7 (9.46 %)	31 (41.89 %)
4	2 (0.25%)	0 (0.00 %)	0 (0.00 %)	0 (0.00 %)
Knee replacement surgery (n=1159)				
1	116 (10.01 %)	43 (37.07 %)	85 (73.28 %)	114 (98.28 %)
2	754 (65.06 %)	58 (7.69 %)	457 (60.61 %)	742 (98.41 %)
3	283 (24.42 %)	4 (1.41 %)	11 (3.89 %)	116 (40.99 %)
4	6 (0.52 %)	0 (0.00 %)	0 (0.00 %)	1 (16.67 %)

4.3. The evaluation for improving timely access to care for hip and knee replacement through the SEM

To conduct a survival analysis for the primary objectives, we excluded patients with priority 4 (n=2) for hip replacement and patients with priority 4 (n=6) for knee replacement because the sample sizes were very small.

4.3.1. Estimated wait times indicators in hip and knee replacement surgery according to priority levels

Table 4.4 presents the estimated WT1, WT2, and TW for hip replacement. The shortest median WT1 was 49 days in patients with priority 1, followed by 75 days in patients with priority 2, and 194.5 days in patients with priority 3. There was a significant difference between WT1 of hip replacements across priority groups (log-rank test: p<.0001) **(Figure 4.2)**. In contrast, patients with priority 3 requiring a total hip replacement surgery had the shortest WT2 at 133 days, followed by patients with priority 1 at 148 days, and priority 2 at 176 days. The log-rank test for difference in WT2 among priority levels was significant, where p=0.0206 **(Figure 4.3)**. Patients

with priority 1 had the shortest TW, with 269 days. Patients with priority 2 and priority 3 had longer TWs than patients with priority 1 (315 days in priority 2, and 476 days in priority 3). The log-rank test for difference in TW across priority was significant, p<.0001 **(Figure 4.4)**.

Table 4.5 shows the estimated WT1, WT2, and TW for knee replacement. Patients with knee replacement assigned priority 1 had the shortest WT1 at 54 days, followed by 82 days in patients with priority 2, and 202 days in patients with priority 3. The log-rank test for differences in WT1 across priority was significant, at p<.0001 **(Figure 4.5)**. The shortest WT2 was 178 days in patients with priority 1, followed by 196 days in patients with priority 3, and 214.5 days in patients with priority 2. The log-rank test for differences in WT2 across priority was not significant, with p=0.4233 **(Figure 4.6)**. The median TW was the shortest in patients with priority 1, at 324.5 days, followed by 413 days in patients with priority 2, and 719 days in patients with priority 3. The log-rank for differences in TW between patients across priority, with p<.0001 **(Figure 4.7)**.

The findings revealed that the SEM improved the WT1. Patients with higher urgent level received consultation sooner than their counterparts. Patients requiring hip and knee replacement with priority 1 had the shortest median WT1, followed by patients with priority 2, and priority 3. An improvement in WT2 by priority in the SEM has not been found in this project. There was a non-significant difference in WT2 by priority for patients with a knee replacement. In contrast, the WT2 for hip replacement surgery was the shortest in patients with priority 3, followed by patients with priority 1 and priority 2. The results found that TW for hip and knee replacement surgery was improved across priority levels. Patients requiring a total hip or knee replacement surgery had TW in order from the shortest to the longest: patients with priority 1, patients with priority 2, and priority 3.

Table 4.4. Estimated wait time for consultation, estimated wait time for surgery, and estimated total wait time by priority - hip replacement (n=806)[a]

Priority	N (%)	Wait time for consultation (WT1)		Wait time for surgery (WT2)		Total wait time (TW)	
		Median (95% CI) (in days)	p-value[b]	Median (95% CI) (in days)	p-value[b]	Median (95% CI) (in days)	p-value[b]
P1	195 (24.19%)	49 (42-54)	<.0001	148 (123-164)	0.0206	269 (220-301)	<.0001
P2	537 (66.63%)	75 (70-80)		176 (163-189)		315 (296-335)	
P3	74 (9.18%)	194.5 (168-208)		133 (101-158)		476 (335-551)	

[a] Excluding patients with priority 4 (n=2) in survival analysis

[b] Significance level p-value < 0.05 for the log-rank test

Table 4.5. Estimated wait time for consultation, estimated wait time for surgery, and estimated total wait times by priority - knee replacement (n=1153)[a]

Priority	N (%)	Wait time for consultation (WT1)		Wait time for surgery (WT2)		Total wait time (TW)	
		Median (95% CI) (in days)	p-value[b]	Median (95% CI) (in days)	p-value[b]	Median (95% CI) (in days)	p-value[b]
P1	116 (10.06%)	54 (46-63)	<.0001	178 (150-201)	0.4233	324.5 (276-372)	**<.0001**
P2	754 (65.39%)	82 (78-85)		214.5 (197-225)		413 (385-440)	
P3	283 (24.54%)	202 (196-210)		196 (176-218)		719 (660-780)	

[a] Excluding patients with priority 4 (n=6) in survival analysis

[b] Significance level p-value < 0.05 for the log-rank test

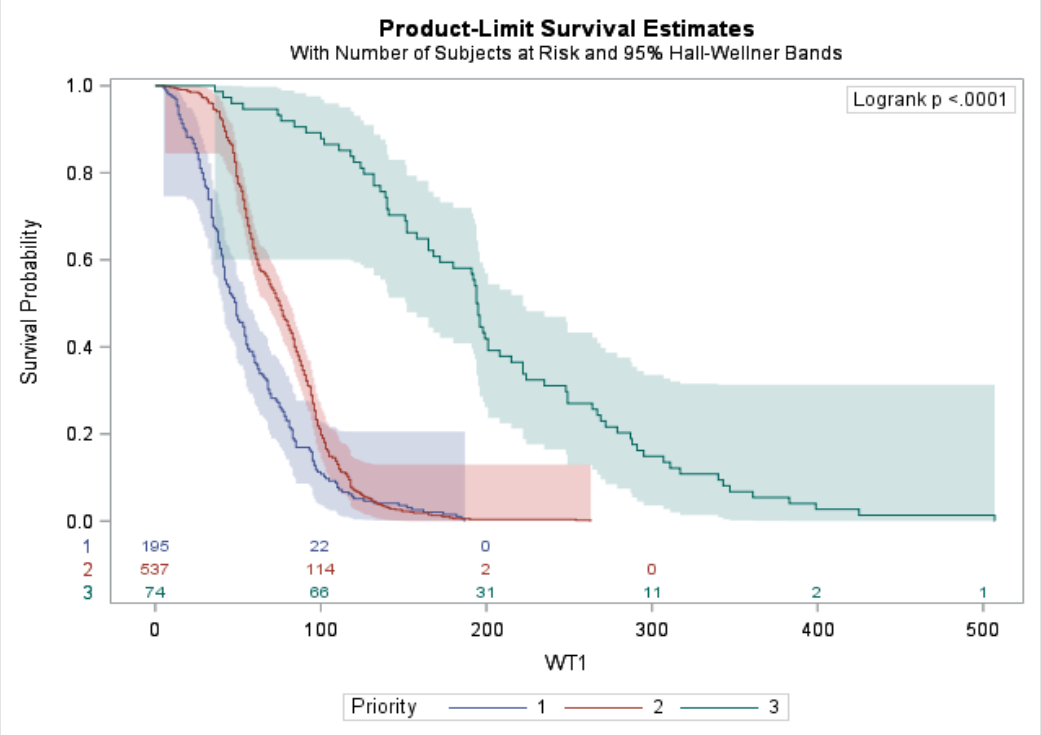

Figure 4.2. Kaplan-Meier survival curves for WT1 by priority - hip replacement (n=806)

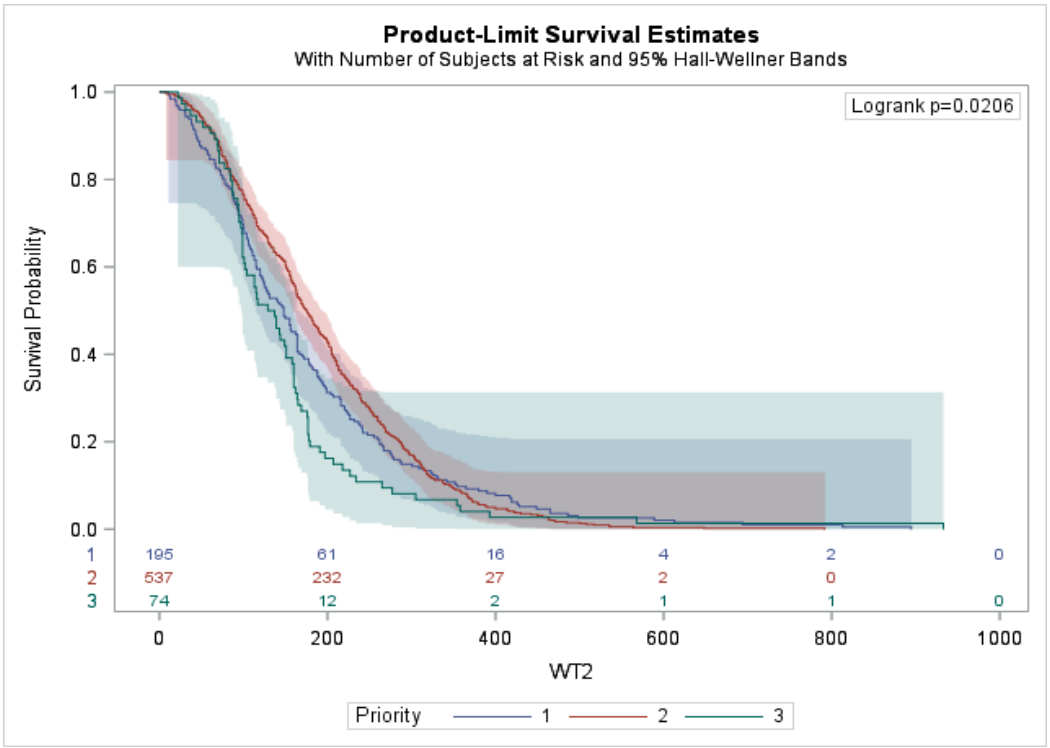

Figure 4.3. Kaplan-Meier survival curves for WT2 by priority - hip replacement (n=806)

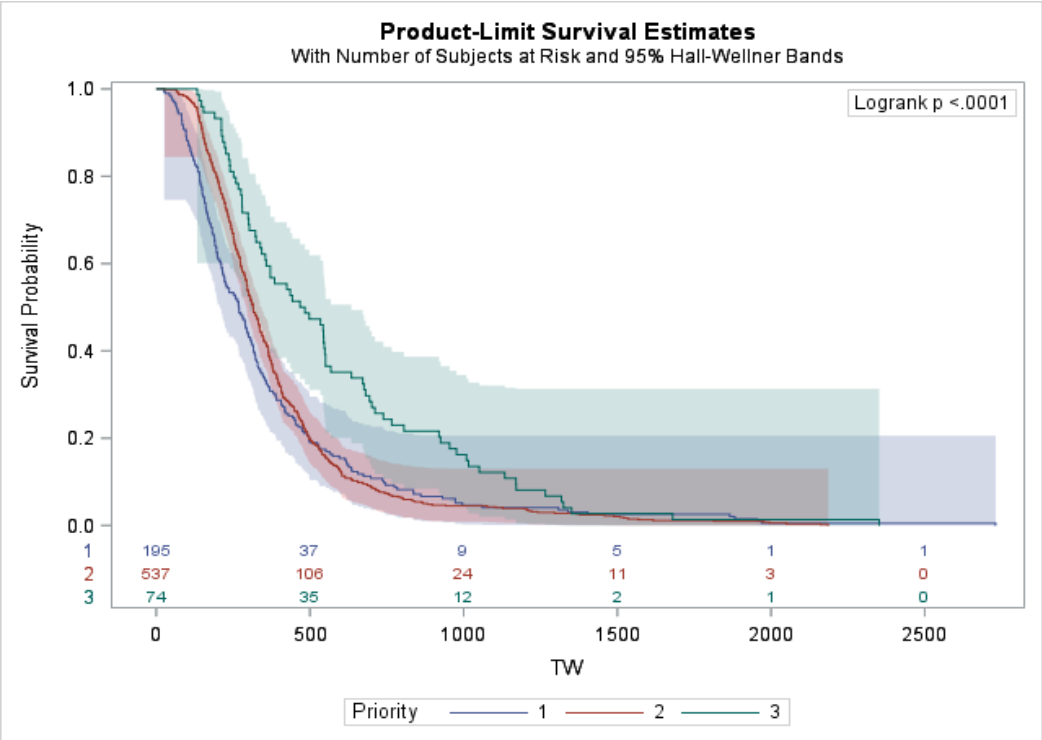

Figure 4.4. Kaplan-Meier survival curves for TW by priority - hip replacement (n=806)

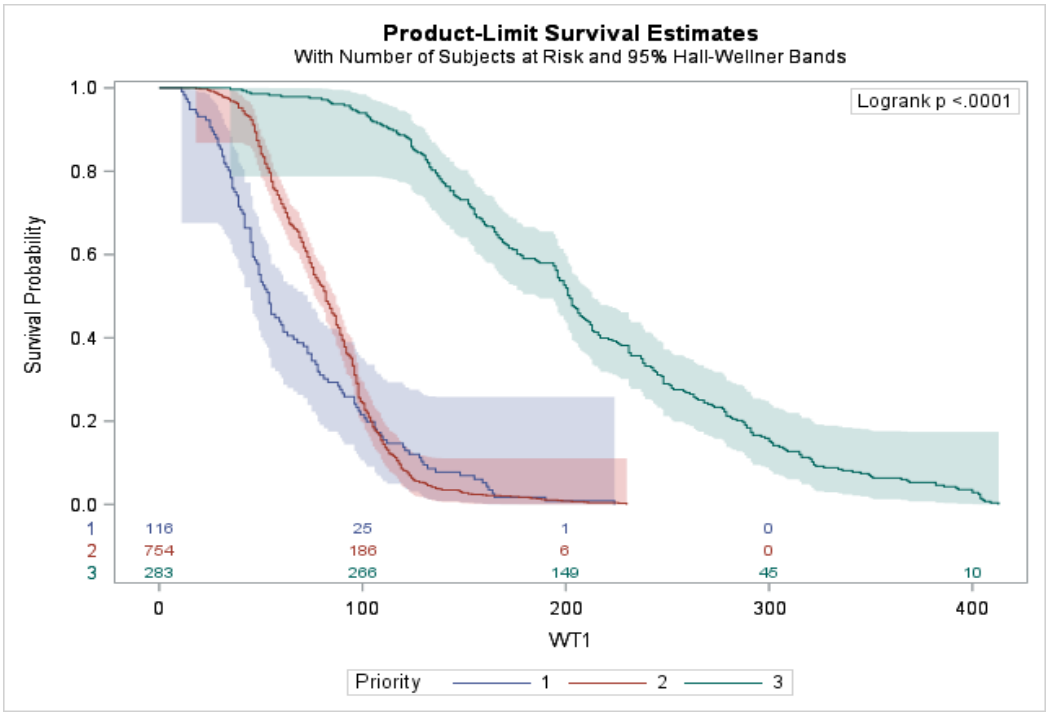

Figure 4.5. Kaplan-Meier survival curves for WT1 by priority - knee replacement (n=1153)

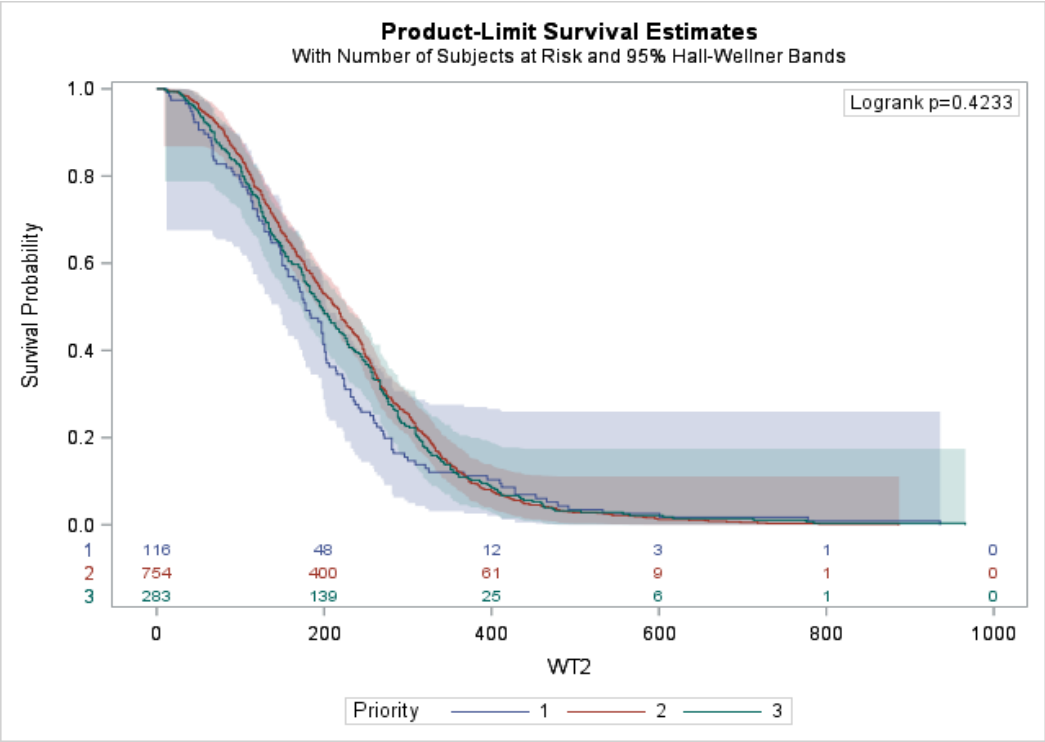

Figure 4.6. Kaplan-Meier survival curves for WT2 by priority - knee replacement (n=1153)

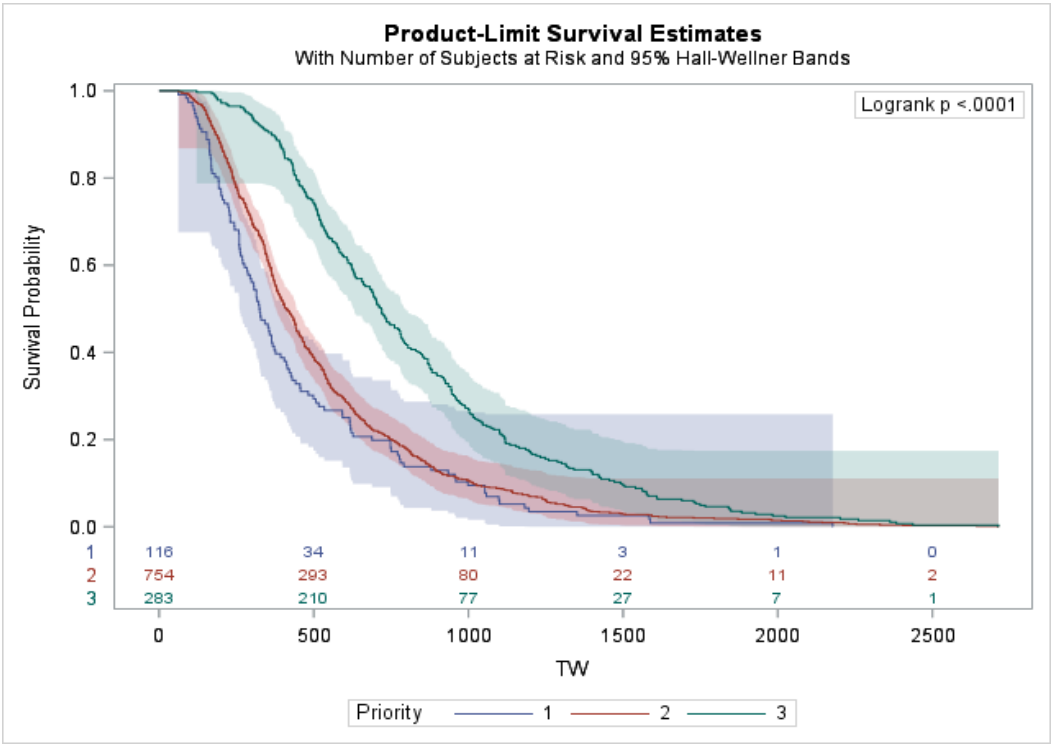

Figure 4.7. Kaplan-Meier survival curves for TW by priority - knee replacement (n=1153)

4.3.2. Factors associated with wait times for hip and knee replacement surgery

Factors associated with wait time for consultation

Table 4.6 presents the results from the multiple Cox regression analysis for WT1 in hip replacement, including covariates and their interactions with time.

For hip replacement surgery, in the multiple Cox regression model, patient's preference for surgeon (p=0.0060), initial referral status (p=0.0126), year of referral (p<.0001), and priority (p<.0001) were predictors. Priority by time interaction and year of referral by time interaction were significant in the model (p<.0001 and p=0.0260, respectively) **(Appendix A4-4)**. After controlling for age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority and their interaction with time, patients with priority 3 and priority 2 were 99.7% (HR=0.003; 95% CI=0.001 - 0.009) and 83.9% (HR=0.161; 95% CI= 0.115 - 0.226) less likely to have a consultation than those with priority 1, initially. However, the parameter associated with interaction between priority levels and time was positive, suggesting that the hazard ratios were increasing over time **(Appendix A4-4)**. Patients with priority 3 and priority 2 were 99.1% (HR=0.009; 95% CI= 0.002 - 0.038) and 52.6% (HR=0.474; 95% CI= 0.216 - 0.954) less likely to have a consultation in 90 days, respectively. Patients choosing the next available surgeon were 1.250 times more likely to have a consultation than those requesting a specific surgeon (HR=1.250; 95% CI=1.066 - 1.466) at any given time. Patients with incomplete referral form status were 1.6 times more likely to have a consultation than patients with completed referral form status (HR=0.626; 95% CI=0.433 - 0.905) at any given time.

Table 4.6. Results from the extended multiple Cox regression model for WT1 including covariates and time-by covariate interactions **-** hip replacement (n=806)

Variables	HR[a]	95% CI	p-value[b]
Patient's preference for surgeon			0.0060
Next available	1.250	1.066 - 1.466	
Specific surgeon	1.000		
Initial referral[c]			0.0126
Incomplete	0.626	0.433 - 0.905	
Complete	1.000		
Year of referral[d]			<.0001
WT1= 0 day			
2011-2013	0.327	0.260 - 0.411	
2014-2016	1.052	0.788 - 1.403	
2017-2019	1.000		
WT1= 90 days			
2011-2013	0.273*	0.198 - 0.411	
2014-2016	0.878*	0.602 - 1.403	
2017-2019	1.000*		
Priority (P)			<.0001
WT1= 0 day			
P3	0.003	0.001 - 0.009	
P2	0.161	0.115 - 0.226	
P1	1.000		
WT1= 90 days			
P3	0.009*	0.002 - 0.038	
P2	0.474*	0.216 - 0.954	
P1	1.000*		

[a] Extended Cox proportional hazard model adjusted for age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, where applicable

[b] Significantly different from reference category, p-value <0.05

[c] A standard referral form status when it was sent to the OCI at the first time by family doctors.

[d] The year when a patient was referred to the OCI for hip and knee replacement assessment

*HRs in 90 days was calculated by the equation: $HR=\exp(\beta_0 + \beta_1 * WT1)$ where β_0 is a coefficient of variable at WT1=0 and β_1 is a coefficient of the interaction between a variable and WT1

Table 4.7 presents the results from the extended multiple Cox regression analysis for WT1 in knee replacement, including covariates and their interactions with time.

For knee replacement surgery**,** in the multiple Cox regression model, patient's preference for surgeon (p<.0001), initial referral incomplete status (p=0.0236), year of referral (p<.0001), and priority (p<.0001) were predictors for WT1. Additionally, priority interaction with time (p<.0001) was significant in model **(Appendix A4-8).** After controlling for age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, patients with priority 3 and priority 2 were 99.8% (HR=0.002; 95% CI=0.001 - 0.006) and 81.9% (HR=0.181; 95% CI=0.124 - 0.264) less likely to have a consultation than those with priority 1, respectively, initially. However, the parameter associated with the interaction between priority levels and time was positive, suggesting that hazard ratios were increasing over time **(Appendix A4-8)**. Patients with priority 3 were 99.0% (HR=0.01; 95% CI=0.002 - 0.033) less likely to have a consultation than those with priority 1, while a difference in the probability of having a consultation in priority 2 than in priority 1 was insignificant (HR=0.698; 95% CI= 0.305 - 1.459) in 90 days. Patients choosing the next available surgeon were 1.411 times more likely to wait a shorter time for consultation than those requesting a specific surgeon (HR=1.411; 95% CI=1.241 - 1.603) throughout the study period. Patients with incomplete referral form status were 1.34 times more likely to prolong WT1 than patients with completed referral form status (HR=0.744; 95% CI=0.576 - 0.961) at any given time.

Table 4.7. Results from the extended multiple Cox regression model for WT1 including covariates and time-by covariate interactions - knee replacement (n=1153)

Variables	HR[a]	95% CI	p-value[b]
Patient's preference for surgeon			<.0001
Next available	1.411	1.241 - 1.603	
Specific surgeon	1.000		
Initial referral[c]			0.0236
Incomplete	0.744	0.576 - 0.961	
Complete	1.000		
Year of referral[d]			<.0001
2011-2013	0.575	0.485 - 0.682	
2014-2016	0.955	0.823 - 1.108	
2017-2019	1.000		
Priority (P)			<.0001
WT1= 0 day			
P3	0.002	0.001 - 0.006	
P2	0.181	0.124 - 0.264	
P1	1.000		
WT1= 90 days			
P3	0.010*	0.002 - 0.033	
P2	0.698*	0.305 - 1.459	
P1	1.000*		

[a] Extended Cox proportional hazard model adjusted for age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, where applicable

[b] Significantly different from reference category, p-value <0.05

[c] A standard referral form status when it was sent to the OCI at the first time by family doctors.

[d] The year when a patient was referred to the OCI for hip and knee replacement assessment

* HRs in 90 days was calculated by the equation: $HR=\exp(\beta_0 + \beta_1 * WT1)$ where β_0 is a coefficient of variable at WT1=0 and β_1 is a coefficient of the interaction between a variable and WT1

Overall, there were association between WT1 and factors, including priority, patient's preference for surgeon, and incomplete initial referral form. Patients with higher urgency level were likely to receive consultation sooner than their counterparts. Patients choosing the next available surgeon had a shorter WT1 than those requesting a specific surgeon. WT1 was longer if the initial referral was incomplete than if the initial referral was complete.

Factors associated with wait time for surgery

Table 4.8. presents the results from the extended multiple Cox regression analysis for WT2 in hip replacement, including covariates and their interactions with time.

In a group of hip replacement surgery, in the multiple Cox regression model for WT2, diagnosis (p=0.0241), patient's preference for surgeon (p=0.0006), and year of referral (p<.0001) were predictors. The patient's preference for surgeon by time interaction (p=0.0164) and year of referral by time interaction (p=0.0319) were significant **(Appendix A4-12)**. After controlling for covariates age group, diagnosis, patient's preference for surgeon, year of referral, priority, and their interactions with time, patients requiring hip replacement surgery due to osteoarthritis was 22.3% less likely to receive a surgery sooner than those requiring hip replacement surgery due to other hip arthritis disorders (HR=0.777; 95% CI=0.624 - 0.967) at any given time. Patients choosing the next available surgeon were 0.603 times as likely to receive a surgery early as those requesting a specific surgeon (HR=0.603; 95% CI=0.452 - 0.803), initially. The parameter associated with the interaction between patient's preference and time was positive, suggesting the hazard ratios were increasing over time **(Appendix A4-12)**. There was an insignificant difference in the likelihood of having a surgery between choosing the next surgeon and requesting a specific surgeon in 182 days (HR=0.867; 95% CI=0.452 - 1.379). The demand of hip replacement surgery was associated with WT2. The referrals in 2014-2016 were 51.9% (HR=0.481; 95% CI=0.341-0.679) less likely to have a shorter WT2 than those in 2017-2019, initially. In fact, the number of referrals were sent to the OCI in 2014-2016 was the largest, approximately 473 referrals compared to 396 referrals in 2011-2013 and 290 referrals in 2017-2019. The parameter associated with interaction between year of referral and time was positive, suggesting that the hazard ratios were increasing over time **(Appendix A4-12)**. Thus, referrals in

2014-2016 were 42.4% less likely to have a surgery than those in 2017-2019 in 182 days (HR=0.578; 95% CI= 0.341 - 0.977).

Table 4.8. Results from the extended multiple Cox regression model for WT2 including covariates and time-by covariate interactions - hip replacement (n=806)

Variables	HR[a]	95% CI	p-value[b]
Diagnosis[c]			0.0241
Osteoarthritis	0.777	0.624 - 0.967	
Others	1.000		
Patient's preference for surgeon			0.0006
WT2= 0 day			
Next available	0.603	0.452 - 0.803	
Specific surgeon	1.000		
WT2= 182 days			
Next available	0.867	0.452 - 1.379	
Specific surgeon	1.000		
Year of referral[d]			<.0001
WT2= 0 day			
2011-2013	0.873	0.703 - 1.084	
2014-2016	0.481	0.341- 0.679	
2017-2019	1.000		
WT2= 182 days			
2011-2013	1.047*	0.703 - 1.560	
2014-2016	0.578*	0.341 - 0.977	
2017-2019	1.000*		

[a] Extended Cox proportional hazard model adjusted for age group, diagnosis, patient's preference for surgeon, year of referral, priority, and their interaction with time, where applicable

[b] Significantly different from reference category, p-value <0.05

[c] Total hip and knee replacement surgery due to osteoarthritis or other arthritis disorders

[d] The year when a patient was referred to the OCI for hip and knee replacement assessment

* HRs in 182 days was calculated by the equation: $HR=\exp(\beta_0 + \beta_1 * WT2)$ where β_0 is a coefficient of variable at WT2=0 and β_1 is a coefficient of the interaction between a variable and WT2

Table 4.9 presents the results from the extended multiple Cox regression analysis for WT2 in knee replacement, including covariates and their interactions with time.

Among patients requiring knee replacement surgery, in the multiple Cox regression model for WT2, patient's preference for surgeon and year of referral were found to be independent predictors (p=0.0183 and p<.0001, respectively). An interaction with time was found only for year

of referral (p=0.0019) **(Appendix A4-16)**. After controlling for covariates: age group, diagnosis, patient's preference for surgeon, year of referral, and their interactions with time, the priority was not included into the final model. Thus, there was not an association between priority levels and WT2. Patients choosing the next available surgeon for consultation were 0.861 times as likely to receive a surgery early as those requesting a specific surgeon (HR=0.861; 95% CI=0.760 - 0.975) at any given time. The demand of referrals might impact WT2. The number of the referrals in 2011-2013 and in 2014-2016 were 35.5 % (HR=0.645; 95% CI=0.535-0.778) and 60.4% (HR=0.396; 95% CI=0.290-0.539) less likely to have a surgery than those in 2017-2019, initially. The parameter associated with the interaction between year of referral and time was positive, suggesting the hazard ratios were increasing over time **(Appendix A4-16)**. The referrals in 2014-2016 were 52.5% (HR=0.475; 95% CI=0.290-0.776) less likely to have a surgery than those in 2017-2019, while the difference in the probability of having a surgery between in 2011-2013 and in 2017-2019 was not significant (HR=0.774; 95% CI = 0.535 - 1.120) in 182 days.

Table 4.9. Results from the extended multiple Cox regression model for WT2 including covariates and time-by covariate interactions - knee replacement (n=1153)

Variables	HR[a]	95% CI	p-value[b]
Patient's preference for surgeon			0.0183
Next available	0.861	0.760 - 0.975	
Specific surgeon	1.000		
Year of referral[c]			<.0001
WT2= 0 day			
2011-2013	0.645	0.535 - 0.778	
2014-2016	0.396	0.290 - 0.539	
2017-2019	1.000		
WT2= 182 days			
2011-2013	0.774*	0.535 - 1.120	
2014-2016	0.475*	0.290 - 0.776	
2017-2019	1.000*		

[a] Extended Cox proportional hazard model adjusted for age group, diagnosis, patient's preference for surgeon, year of referral, priority, and their interaction with time, where applicable

[b] Significantly different from reference category, p-value <0.05

[c] The year when a patient was referred to the OCI for hip and knee replacement assessment

* HRs in 182 days was calculated by the equation: $HR=\exp(\beta_0 + \beta_1 * WT2)$ where β_0 is a coefficient of variable at WT2=0 and β_1 is a coefficient of the interaction between a variable and WT2

In brief, although the association between priority levels and WT2 was not found, but other factors including diagnosis (e.g., hip osteoarthritis), patient's preference for surgeon, and the demand of hip and knee replacement impacted WT2 through the SEM. Choosing the next available surgeon for consultation was more likely to have a longer WT2 than requesting a specific surgeon at the time when patients and surgeons decided to have a hip replacement surgery. The likelihood of having a hip replacement surgery was increasing over time among patients choosing the next surgeon. In contrast, the choosing the next available surgeon was more likely to have a longer WT2 than requesting a specific surgeon in patients with knee replacement at any given time. An increase in the demand of hip and knee surgery might prolong WT2.

Factors associated with a total wait time

Table 4.10 showed results from the extended multiple Cox regression analysis for TW in hip and knee replacement, including covariates and their interactions with time.

For hip replacement surgery, age group (p=0.0154), diagnosis (p=0.0143), year of referral (p<.0001), and priority (p<.0001), were predictors on TW in the multiple Cox regression model. Priority by time interaction was significant (p=0.0005) in the model **(Appendix A4-20).** After controlling for covariates: age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, patients with priority 3 and priority 2 were 69.1% (HR=0.309; 95% CI=0.197 - 0.486) and 35.7% (HR=0.643; 95% CI=0.518 - 0.799) less likely to have a surgery since being referred by family doctors than those with priority 1, respectively. The parameter associated with the interaction between priority and time was positive, suggesting that the hazard ratios were increasing over time **(Appendix A4-20).** In 272 days (90 days waiting for consultation plus 182 days waiting for surgery), patients with priority 3 were 59.4% (HR=0.406; 95% CI=0.197-0.638) less likely to have a surgery since they were referred by family doctors than those with priority 1, while a difference in the likelihood of having a surgery since referrals were referred by family doctors between patients with priority 2 and with priority 1 was not significant (HR=0.845; 95% CI= 0.518 - 1.049). Patients under 65 were 16.2% less likely to have a shorter TW than patients aged 65 or older (HR=0.838; 95% CI=0.726 - 0.967) at any given time. Patients with osteoarthritis were 1.33 times more likely to have a longer TW than their counterparts (HR=0.753; 95% CI=0.600 - 0.945) at any given time.

Table 4.10. Results from the extended multiple Cox regression model for TW including covariates and time-by covariate interactions - hip replacement (n=806)

Variables	HR[a]	95% CI	p-value[b]
Age group			0.0154
< 65	0.838	0.726 - 0.967	
≥ 65	1.000		
Diagnosis[c]			0.0143
Osteoarthritis	0.753	0.600 - 0.945	
Others	1.000		
Year of referral[d]			<.0001
2011-2013	0.420	0.347 - 0.510	
2014-2016	0.526	0.444 - 0.624	
2017-2019	1.000		
Priority (P)			<.0001
TW= 0 day			
P3	0.309	0.197 - 0.486	
P2	0.643	0.518 - 0.799	
P1	1.000		
TW = 272 days			
P3	0.406*	0.197 - 0.638	
P2	0.845*	0.518 - 1.049	
P1	1.000*		

[a] Extended Cox proportional hazard model adjusted for age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, where applicable

[b] Significantly different from reference category, p-value <0.05

[c] Total hip and knee replacement surgery due to osteoarthritis or other arthritis disorders

[d] The year when a patient was referred to the OCI for hip and knee replacement assessment

[*] HRs in 272 days was calculated by the equation: $HR=\exp(\beta_0 + \beta_1 * TW)$ where β_0 is a coefficient of variable at TW=0 and β_1 is a coefficient of the interaction between a variable and TW

Table 4.11 presents the results from the extended multiple Cox regression analysis for TW in hip and knee replacement, including covariates and their interactions with time.

For knee replacement surgery, age group (p=0.001), year of referral (p<.0001), and priority (p<.0001) were predictors on TW in the multiple Cox regression model. Besides, both year of referral's and priority's interaction with time were significant in model (p<.0001) **(Appendix A4-24)**. After controlling for covariates: age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, patients with priority 3 and priority 2 were 83.0% (HR=0.170; 95% CI=0.115 - 0.251) and 54.3% (HR=0.457; 95% CI=0.363 - 0.575) less likely to have a surgery than those with priority 1, respectively, at the time when the patients were referred by their family doctors. The parameter associated with the interaction between priority and time was positive, suggesting that hazard ratios were increasing over time **(Appendix A4-24)**. Patients with priority 3 and priority 2 were 77.6% (HR=0.224; 95% CI= 0.151-0.330), and 40.0% (HR=0.60; 95% CI= 0.477-0.755) less likely to have a surgery since they were referred by family doctors in 272 days (90 days waiting for consultation and 182 days waiting for surgery). Patients under 65 were 18.0% less likely to have a shorter TW than patients aged 65 or older (HR=0.820; 95% CI=0.728 - 0.923) throughout the study period.

Table 4.11. Results from the extended multiple Cox regression model for TW including covariates and time-by covariate interactions - knee replacement (n=1153)

Variables	HR[a]	95% CI	p-value[b]
Age group			0.001
< 65	0.820	0.728 - 0.923	
≥ 65	1.000		
Year of referral[c]			<.0001
TW= 0 day			
2011-2013	0.258	0.214 - 0.312	
2014-2016	0.219	0.161 - 0.299	
2017-2019	1.000		
TW = 272 days			
2011-2013	0.339	0.214 - 0.409	
2014-2016	0.288	0.161 - 0.393	
2017-2019	1.000		
Priority (P)			<.0001
TW= 0 day			
P3	0.170	0.115 - 0.251	
P2	0.457	0.363 - 0.575	
P1	1.000		
TW = 272 days			
P3	0.224*	0.151 - 0.330	
P2	0.600*	0.477 - 0.755	
P1	1.000*		

[a] Extended Cox proportional hazard model adjusted for age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, priority, and their interaction with time, where applicable

[b] Significantly different from reference category, p-value <0.05

[c] The year when a patient was referred to the OCI for hip and knee replacement assessment

* HRs in 272 days was calculated by the equation: $HR=\exp(\beta_0 + \beta_1 * TW)$ where β_0 is a coefficient of variable at TW=0 and β_1 is a coefficient of the interaction between a variable and TW

Overall, the SEM improved a TW for hip and knee replacement surgery. Patients with higher urgency had a shorter TW than their counterparts. Moreover, patients under 65 were more likely to delay access to care than patients aged 65 or older. Hip osteoarthritis was a factor associated with TW in the SEM.

4.3.3. Compare the total median wait time between hip and knee replacement in each priority group

Among patients with priority 1, patients with knee replacement surgery had a longer TW than patients with hip replacement, with 324 days and 269 days, respectively (log-rank test: p=0.0291). Similarly, a TW was 413 days for patients with knee replacement surgery in priority 2, higher than that for patients with hip replacement in priority 2, approximately 315 days (log-rank test: p<.0001). Patients with knee replacement in priority 3 had a TW of 719 days, while patients with hip replacement in priority 3 had a shorter TW, roughly 476 days (log-rank test: p<.0001) **(Table 4.12).**

Table 4.12. Comparisons of the total median wait time between hip and knee replacement in each priority group

Type	N	Priority 1		Priority 2		Priority 3	
		Median (95% CI) (in days)	p-value[a]	Median (95% CI) (in days)	p-value[a]	Median (95% CI) (in days)	p-value[a]
Hip	806	269 (220-301)	0.0291	315 (296-335)	<.0001	476 (355-551)	<.0001
Knee	1153	324.50 (208-604.5)		413 (385-440)		719 (660-780)	

[a] Significance level p-value <0.05 for the log-rank test

4.4. Factors impact the receiving consultation and surgery for hip and knee replacement in the SEM

4.4.1. Factors impact the receiving consultation within the benchmark of 90 days

Factors associated with receiving consultation within 90 days for hip replacement

A multiple logistic regression model including the age group, diagnosis, patient's preference for surgeon, incomplete referral form status, year of referral, and priority had goodness-of-fit, with Hosmer and Lemeshow Goodness-of-fit test p=0.0678 (**Appendix A4-25**). Our model's ROC curve had a value of 0.7665 that is considered acceptable discrimination, with a statistical significance ROC Contrast test, p<.0001 **(Appendix A4-26, Figure 4.8)**. Additionally, the multicollinearity assumption was met (i.e. there was no multicollinearity) **(Appendix A4-33, A4-34).**

Influential factors associated with MAWT of 90 days for consultation are shown from the univariate logistic regression analysis and the multiple logistic regression analysis in **Table 4.13**. After adjusting for age group, diagnosis, patient's preference for surgeon, incomplete referral form, year of referral, and priority, the association between having consultation within a benchmark of 90 days and factors, including age (OR=0.895; 95% CI: 0.638 - 1.257), diagnosis (OR=0.914; 95% CI: 0.523 - 1.596), patient's preference for surgeon (OR=1.310, 95% CI: 0.900 - 1.908), and incomplete referral form (OR= 0.512; 95% CI: 0.233 - 1.124) were not significant. The odds ratio for priority 2 (versus priority 1) was 0.256, with 95% CI (0.161 - 0.407). Thus, a patient assigned a priority 2 was 74.4% less likely to have consultation within 90 days than a patient with priority 1. The odds ratio for priority 3 (versus priority 1) was 0.017, with 95% CI (0.007 - 0.043). A patient with priority 3 was 98.3% less likely to receive a consultation within the benchmark than a patient with priority 1. The odds ratio for referrals in the 2011-2013 period

(versus in the 2017-2019 period) was 0.182, with 95% CI (0.115 - 0.288). A referral in the 2017-2019 period was 5.5 times as likely to have consultation within 90 days than a referral in the 2011-2013 period. There was no difference in receiving a consultation within 90 days between the 2014-2016 period and the 2017-2019 period (OR=0.673; 95% CI: 0.442 - 1.025).

Table 4.13. The results from the univariate logistic regression model and the multiple logistic regression model for receiving consultation within 90 days - hip replacement (n=806)

Variables	Univariate logistic regression			Multiple logistic regression		
	ORs	95% CI	p-value[b]	ORs[a]	95% CI	p-value[b]
Age group			0.0105			0.5233
< 65	0.683	0.511 - 0.915	0.0105	0.895	0.638 - 1.257	0.5233
≥ 65	1.000			1.000		
Diagnosis			0.6352			0.7515
Osteoarthritis	1.115	0.711 - 1.750	0.6352	0.914	0.523 - 1.596	0.7515
Others	1.000			1.000		
Patient's preference for surgeon			0.3662			0.1585
Next available	1.159	0.842 - 1.596	0.3662	1.310	0.900 - 1.908	0.1585
Specific surgeon	1.000			1.000		
Initial referral			0.0115			0.0954
Incomplete	0.398	0.195 - 0.813	0.0115	0.512	0.233 - 1.124	0.0954
Complete	1.000			1.000		
Year of referral			<.0001			<.0001
2011-2013	0.197	0.133 - 0.293	<.0001	0.182	0.115 - 0.288	<.0001
2014-2016	0.569	0.387 - 0.838	0.0043	0.673	0.442 - 1.025	0.0654
2017-2019	1.000			1.000		
Priority			<.0001			<.0001
P3	0.021	0.009 - 0.050	<.0001	0.017	0.007 - 0.043	<.0001
P2	0.404	0.267 - 0.612	<.0001	0.256	0.161 - 0.407	<.0001
P1	1.000			1.000		

[a] Odd ratios were adjusted for covariates, including age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, and priority

[b] Significantly different from reference category, p-value <0.05

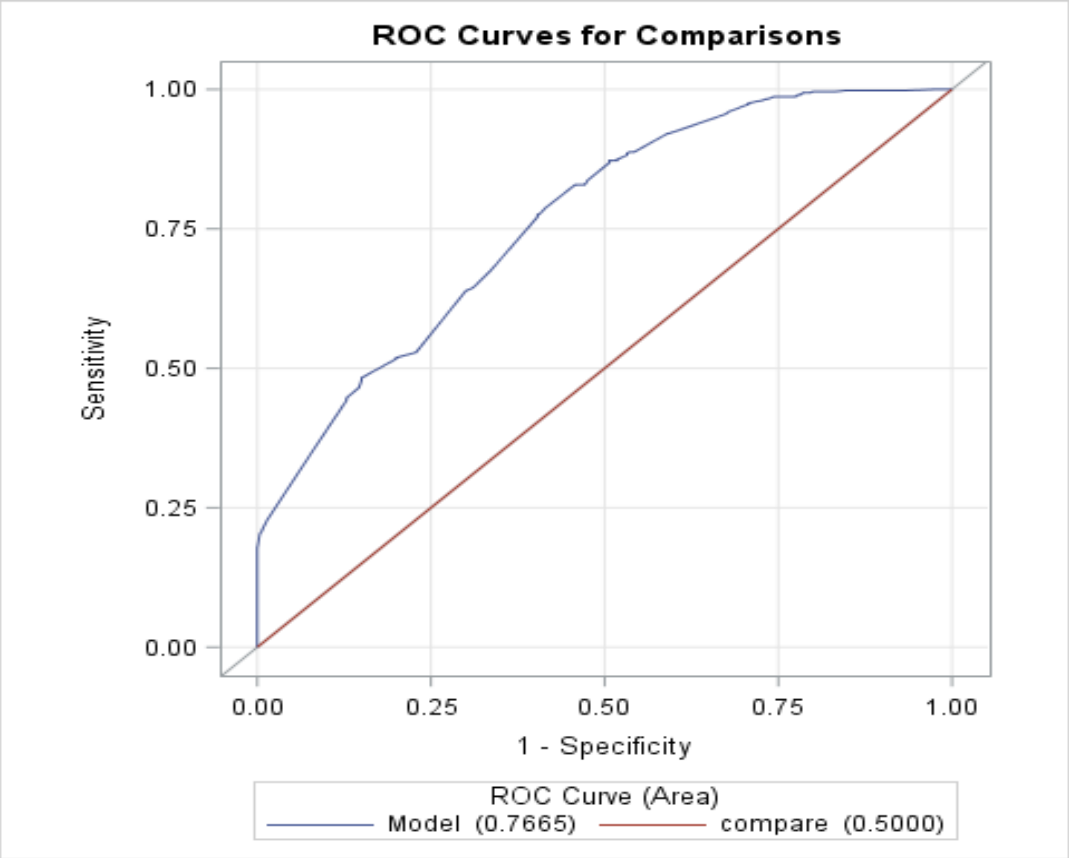

Figure 4.8. ROC Curve for selected model for WT1 - hip replacement

Factors associated with receiving consultation within 90 days for knee replacement

A multiple logistic regression model including the age group, diagnosis, patient's preference for surgeon, incomplete referral form status, year of referral, primary joint affected, and priority was a model fit, with Hosmer and Lemeshow Goodness-of-fit test p=0.2589 (**Appendix A4-27**). Our model's ROC curve had a value of 0.8044 that is considered excellent discrimination, with a statistical significance ROC Contrast test, p<.0001 (**Appendix A4-28, Figure 4.9**). Additionally, the multicollinearity assumption was met **(Appendix A4-35, A4-36).**

The association between influential factors and receiving a consultation within 90 days were shown from the univariate logistic regression analysis and the multiple logistic regression

analysis in **Table 4.14**. After adjusting for age group, diagnosis, patient's preference for the surgeon, incomplete referral form, year of referral, and priority, the association between having a consultation within a benchmark of 90 days and factors, including age group (OR=0.922; 95% CI: 0.697 - 1.220), and incomplete referral form (OR=0.657; 95% CI: 0.357 - 1.212) was not significant. The odd ratios for diagnosis were 0.562, with 95% CI (0.340 - 0.931). A patient requiring a knee replacement surgery due to osteoarthritis was 43.8% less likely to receive consultation than a patient needing knee replacement surgery due to other knee arthritis disorders. The odds ratio for patient's preference for the surgeon was 1.600, with 95% CI (1.196 - 2.141). A patient choosing a next available for consultation was 1.6 times more likely to have consultation within 90 days.

The odds ratio for priority 2 (versus priority 1) was 0.341, with 95% CI (0.211 - 0.549). Thus, a patient with priority 2 was 65.9% less likely to have consultation within 90 days than a patient with priority 1. The odds ratio for priority 3 (versus priority 1) was 0.01, with 95% CI (0.005 - 0.021). A patient with priority 3 was 99% less likely to receive consultation within the benchmark than a patient with priority 1. The odds ratio for referrals in the 2011-2013 period (versus in the 2017-2019 period) was 0.325, with 95% CI (0.219 - 0.483). A referral in 2017-2019 was 3.1 times more likely to have a consultation within 90 days than a referral in 2011-2013. There was no difference in receiving a consultation within 90 days between 2014-2016 and 2017-2019 (OR=0.787; 95% CI: 0.561 - 1.104).

Table 4.14. The results from the univariate logistic regression model and the multiple logistic regression model for receiving consultation within 90 days - knee replacement (n=1153)

Variables	Univariate logistic regression			Multiple logistic regression		
	ORs	95% CI	p-value[b]	ORs[a]	95% CI	p-value[b]
Age group			0.0089			0.5706
< 65	0.734	0.582 - 0.925	0.0089	0.922	0.697 - 1.220	0.5706
≥ 65	1.000			1.000		
Diagnosis			0.2373			0.0252
Osteoarthritis	1.249	0.864 - 1.804	0.2373	0.562	0.340 - 0.931	0.0252
Others	1.000			1.000		
Patient's preference for surgeon			0.7319			0.0016
Next available	1.044	0.816 - 1.335	0.7319	1.600	1.196 - 2.141	0.0016
Specific surgeon	1.000			1.000		
Initial referral			0.0177			0.1790
Incomplete	0.535	0.319 - 0.897	0.0177	0.657	0.357 - 1.212	0.1790
Complete	1.000			1.000		
Year of referral			<.0001			<.0001
2011-2013	0.234	0.169 - 0.324	<.0001	0.325	0.219 - 0.483	<.0001
2014-2016	0.683	0.506 - 0.922	0.0126	0.787	0.561 - 1.104	0.1660
2017-2019	1.000			1.000		
Priority			<.0001			<.0001
P3	0.015	0.007 - 0.031	<.0001	0.010	0.005 - 0.021	<.0001
P2	0.561	0.363 - 0.868	0.0095	0.341	0.211 - 0.549	<.0001
P1	1.000			1.000		

[a] Odd ratios were adjusted for covariates, including age group, diagnosis, patient's preference for surgeon, initial referral, year of referral, and priority

[b] Significantly different from reference category, p-value <0.05

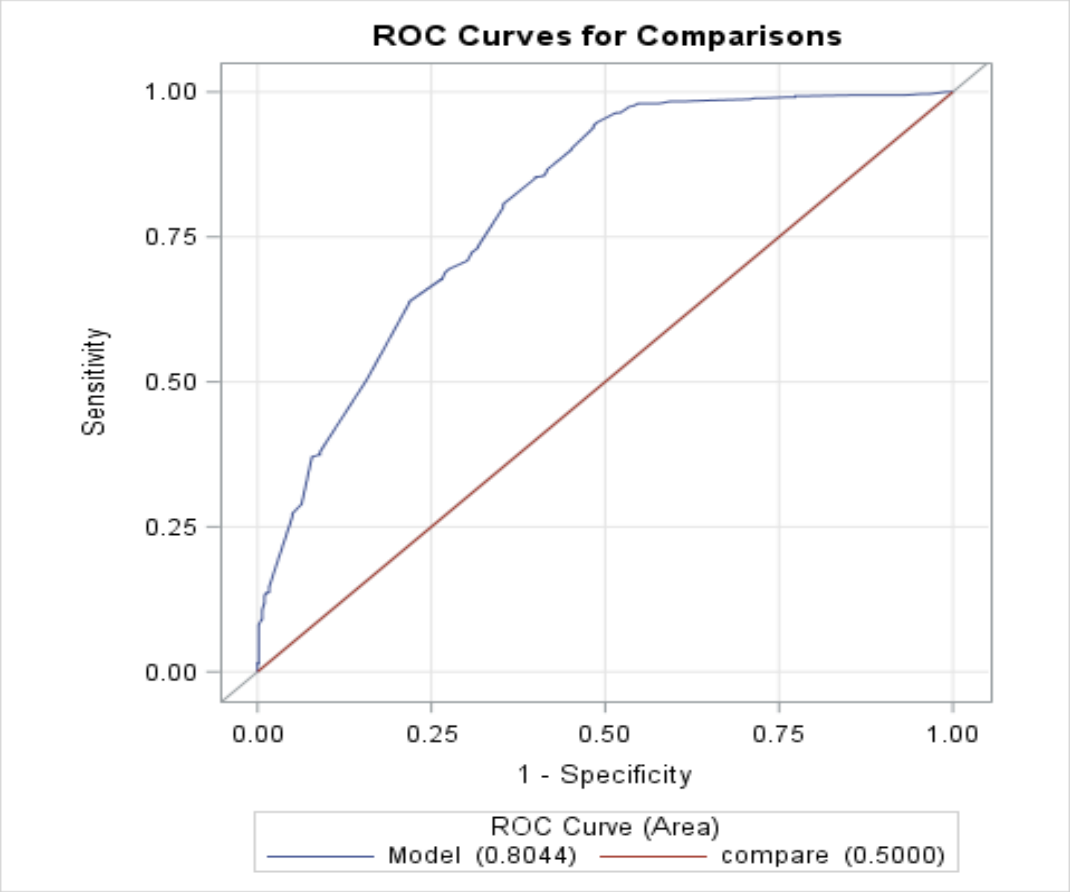

Figure 4.9. ROC Curve for selected model for WT1 - knee replacement

Overall, there were influential factors associated with the likelihood of having a consultation within a benchmark of 90 days. A patient choosing a next surgeon for knee replacement consultation was more likely to receive a consultation within 90 days than a patient requesting a specific surgeon, while there was no association between patient's preference and receiving a consultation for hip replacement surgery. A patient requiring a knee replacement surgery due to osteoarthritis was less likely to receive a consultation within 90 days than a patient needing a knee replacement surgery due to other arthritis disorders. There was an association between priority levels and receiving a consultation within 90 days. Patients with higher urgent levels were more likely to have consultation within the benchmark than those with lower urgent levels.

4.4.2. Factors associated with the receiving surgery within a benchmark of 182 days

Factors associated with receiving surgery within 182 days for hip replacement

A multiple logistic regression model including the age group, diagnosis, patient's preference for surgeon, year of referral, and priority was a goodness-of-fit model, with Hosmer and Lemeshow Goodness-of-fit test p=0.7689 (**Appendix A4-23**). Our model's ROC curve had a value of 0.6579 that is considered acceptable discrimination, with a statistical significance ROC Contrast test, p<.0001 (**Appendix A4-24, Figure 4.10**). Additionally, the assumption about multicollinearity was met **(Appendix A4-31, A4-32).**

The association between influential factors and receiving surgery within 182 days is shown from the univariate logistic regression analysis and the multiple logistic regression analysis in **Table 4.15**. After adjusting for age, diagnosis, patient's preference for surgeon, year of referral, and priority, there was no significant association between having surgery within a benchmark of 182 days and factors, including age group (OR=1.042; 95% CI: 0.774 - 1.404), and diagnosis (OR=0.854; 95% CI: 0.529 - 1.377). The odds ratio for patient's preference for surgeon were 0.65, with 95% CI (0.466 - 0.908), and was found to be significant. A patient choosing the next available for consultation was 35% less likely to have surgery within 182 days than a patient requesting a specific surgeon for consultation. A patient whose referral was in 2014-2016 was 53% less likely to have surgery within 182 days than a patient whose referral was in 2017-2019 (OR=0.470; 95% CI: 0.332 - 0.664), was also found to be significant. There was no difference in receiving surgery within 182 days between a patient referred to the OCI clinic in 2011-2013 and a patient referred to the OCI clinic in 2017-2019 (OR=1.229; 95% CI: 0.834 - 1.812). A patient with priority 3 was approximately 2.618 times more likely to have surgery within 182 days than a patient with priority 1 (OR=2.618; 95% CI: 1.340 - 5.111), but a difference in receiving a surgery

within 182 days between a patient with priority 2 and a patient with priority 1 was not significant (OR=0.761; 95% CI: 0.535 - 1.084).

Table 4.15. The results from the univariate logistic regression model and the multiple logistic regression model for receiving surgery within 182 days - hip replacement (n=806)

Variables	Univariate logistic regression			Multiple logistic regression		
	ORs	95% CI	p-value[b]	ORs[a]	95% CI	p-value[b]
Age group			0.6060			0.7855
< 65	1.077	0.813 - 1.426	0.6060	1.042	0.774 - 1.404	0.7855
≥ 65	1.000			1.000		
Diagnosis			0.1162			0.5170
Osteoarthritis	0.695	0.441 - 1.094	0.1162	0.854	0.529 - 1.377	0.5170
Others	1.000			1.000		
Patient's preference for surgeon			0.0278			0.0114
Next available	0.701	0.511 - 0.962	0.0278	0.650	0.466 - 0.908	0.0114
Specific surgeon	1.000			1.000		
Year of referral			<.0001			<.0001
2011-2013	1.428	0.985 - 2.072	0.0602	1.229	0.834 - 1.812	0.2979
2014-2016	0.505	0.361 - 0.707	<.0001	0.470	0.332 - 0.664	<.0001
2017-2019	1.000			1.000		
Priority			0.0100			0.0004
P3	2.509	1.309 - 4.807	0.0056	2.618	1.340 - 5.111	0.0048
P2	0.643	0.459 - 0.900	0.0100	0.761	0.535 - 1.084	0.1303
P1	1.000			1.000		

[a] Odd ratios were adjusted for covariates, including age group, diagnosis, patient's preference for surgeon, year of referral, and priority

[b] Significantly different from reference category, p-value <0.05

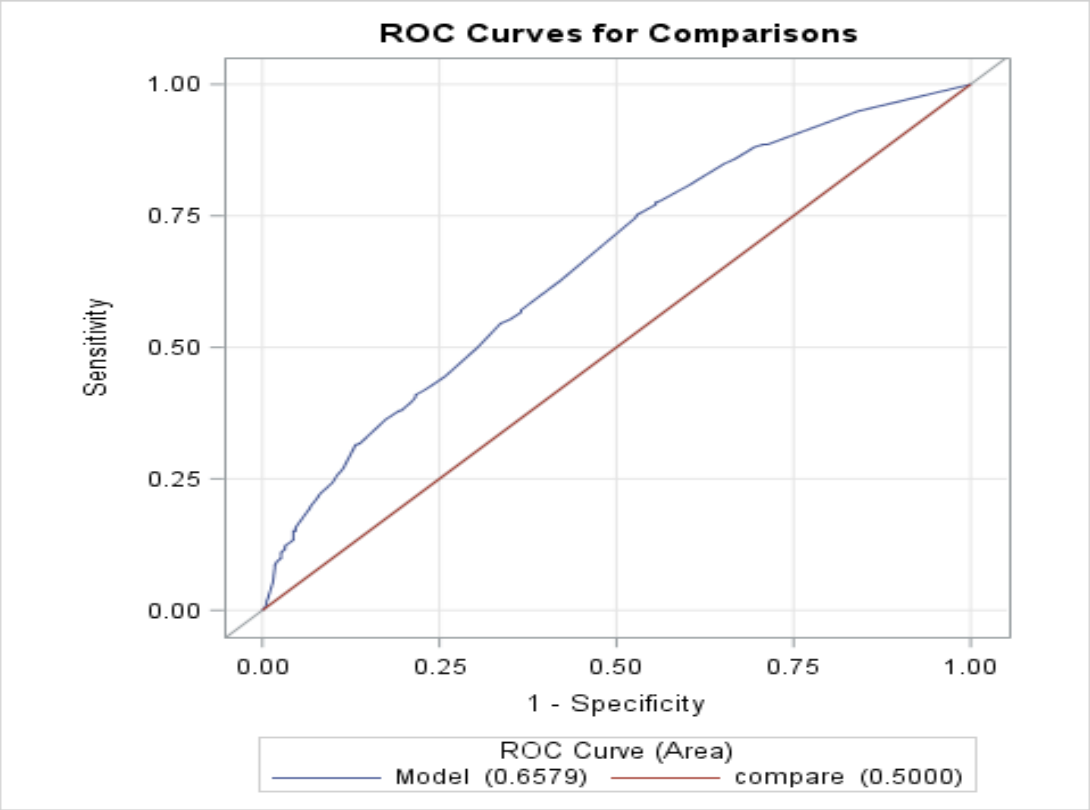

Figure 4.10. ROC Curve for selected model for WT2 - hip replacement

Factors associated with the receiving surgery within 182 days for knee replacement

A multiple logistic regression model including in the age group, diagnosis, patient's preference for surgeon, year of referral, and priority was a model fit, with Hosmer and Lemeshow Goodness-of-fit test p=0.1271 (**Appendix A4-25**). Our model's ROC curve had the value of 0.6198 that is considered acceptable discrimination, with a statistical significance ROC Contrast test, p<.0001 (**Appendix A4-26, Figure 4.11**). Additionally, the multicollinearity assumption was met **(Appendix A4-33, A4-34).**

Influential factors associated with MAWT of 90 days for consultation are shown from the univariate logistic regression analysis and the multiple logistic regression analysis in **Table 4.16.** After adjusting for age group, diagnosis, patient's preference for surgeon, year of referral, and

priority, there was no significant association between having surgery within 182 days and factors, including age group (OR=0.835; 95% CI: 0.655 - 1.064), diagnosis (OR=0.760; 95% CI: 0.520 - 1.112), and priority (p=0.5530). The odds ratio for patient's preference for surgeon was 0.737 and was a significant factor, with 95% CI (0.570 - 0.951). A patient choosing the next available for consultation was 26.3% less likely to have surgery within 182 days than a patient requesting a specific surgeon for consultation. A patient whose referral was in 2014-2016 was 55.7% less likely to have surgery within 182 days than a patient whose referral was in 2017-2019 (OR=0.470; 95% CI: 0.332 - 0.664). There was no difference in receiving surgery within 182 days between a patient whose referral was in 2011-2013 and a patient whose referral was in 2017-2019 (OR=0.849; 95% CI: 0.612 - 1.177).

Table 4.16. The results from the univariate logistic regression model and the multiple logistic regression model for receiving surgery within 182 days - knee replacement (n=1153)

Variables	Univariate logistic regression			Multiple logistic regression		
	ORs	95% CI	p-value[b]	ORs[a]	95% CI	p-value[b]
Age group			0.1331			0.1454
< 65	0.836	0.662 - 1.056	0.1331	0.835	0.655 - 1.064	0.1454
≥ 65	1.000			1.000		
Diagnosis			0.1156			0.1578
Osteoarthritis	0.746	0.517 - 1.075	0.1156	0.760	0.520 - 1.112	0.1578
Others	1.000			1.000		
Patient's preference for surgeon			0.0078			0.0191
Next available	0.715	0.559 - 0.915	0.0078	0.737	0.570 - 0.951	0.0191
Specific surgeon	1.000			1.000		
Year of referral			<.0001			<.0001
2011-2013	0.891	0.657 - 1.207	0.4563	0.849	0.612 - 1.177	0.3250
2014-2016	0.434	0.321 - 0.586	<.0001	0.443	0.327 - 0.600	<.0001
2017-2019	1.000			1.000		
Priority			0.1501			0.5530
P3	0.798	0.518 - 1.230	0.3063	0.895	0.572 - 1.402	0.6293
P2	0.693	0.469 - 1.026	0.0668	0.810	0.538 - 1.221	0.3151
P1	1.000			1.000		

[a] Odd ratios were adjusted for covariates, including age group, diagnosis, patient's preference for surgeon, year of referral, and priority

[b] Significantly different from reference category, p-value <0.05

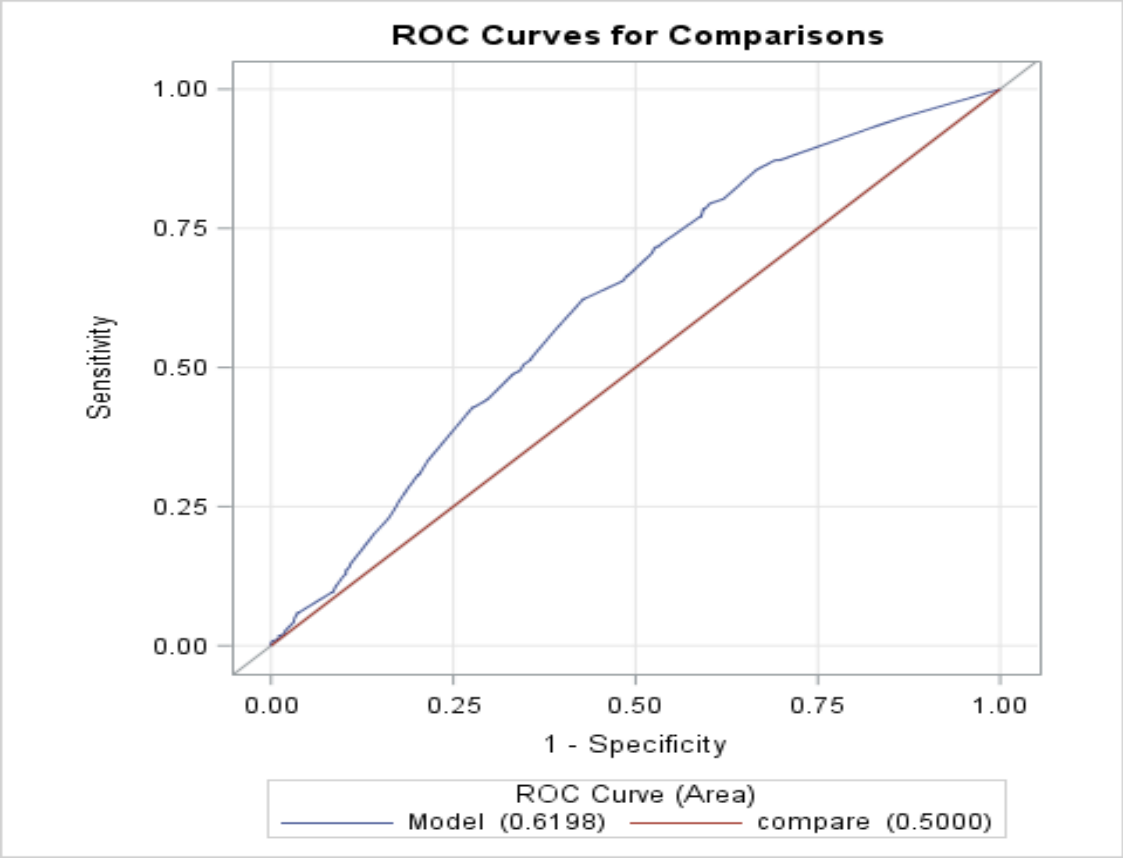

Figure 4.11. ROC Curve for selected model for WT2 - knee replacement

In brief, an association between influential factors and the receiving surgery within 182 days was established. Patients choosing the next available surgeon for consultation were less likely to have surgery within a benchmark of 182 days than those requesting a specific surgeon. The difference in the receiving surgery within a benchmark of 182 days and priority levels was not significant in knee replacement surgery but was significant in hip replacement surgery. A patient with priority 3 was more likely to have hip replacement surgery within a benchmark of 182 days than a patient with priority 1 and priority 2.

Chapter 5. Discussion and Conclusion

This chapter contains four sections: Section 5.1. discusses the improvement in timely access to care for hip and knee replacement through the SEM, Section 5.2. discusses factors that impact receiving consultation and surgery within the established benchmarks for hip and knee replacement in the SEM, Section 5.3. implications of the study findings, Section 5.4. presents strengths and limitations existing in this study, and Section 5.5. provides a conclusion.

5.1. The improvement timely access to care for hip and knee replacement through the single-entry model

5.1.1. The improvement in wait time for consultation

Most studies demonstrated an improvement of WT1 in patients with hip and knee replacement through the SEM. Additionally, WT1 in the SEM for hip and knee replacement was reported for all priorities combined. After implementing surgeon-led multidisciplinary central intake clinics, some health regions in BC shortened the WT1, with 17.8 weeks (124.6 days) in Interior Health, 25.2 weeks (176.4 days) in Vancouver Coastal Health, and 15.7 weeks (109.9 days) in Island Health.[127] Central Intake clinics within the Toronto Central Local Health Integration Network (TC LHIN) had a WT1 less than 100 days.[55] Although WT1 was roughly 21 days in the evaluation of the Alberta Hip and Knee Joint Replacement (2006), the WT1 in Alberta increased from 17.7 weeks (123.9 days) in 2011/2012 to 27.1 weeks (189.7 days) in 2017/2018.[128]

In our study, the SEM improved WT1 in hip and knee replacement surgery. Before implementing an OCI clinic, the 2006-2010 reports from the Fraser Institute[11,14-17] showed that a median wait time to see an orthopedic surgeon for consultation was 24 weeks (168 days) in 2006 to 39.3 weeks (210 days) in 2010. After implementing the OCI clinic, a median WT1 for hip

replacement by priority was 49 days in priority 1, 75 days in priority 2, and 194.5 days in priority 3. A median WT1 for knee replacement by priority was 54 days in priority 1, 82 days in priority 2, and 202 days in priority 3.

5.1.2. The improvement in wait time for surgery

In the literature, the SEM improves not only WT1 but also WT2. Doerr et al.[86] identified that WT2 was shortened from 18 to 8 months after the Orthopedic Unit of the Repatriation General Hospital in Adelaide implemented a SEM to improve timely access. The Alberta Hip and Knee Joint Replacement (2006)[49] showed that WT2 was in 7.5 weeks in the new model compared to 58 weeks under regular care. Another SEM at the Fraser Health Authority[53] reduced WT2 from 278 days to 106 days for hip replacement, and 320 days to 106 days for knee replacement between 2015 and 2019. Similarly, Damani et al.[48] revealed that WT2 was reduced from 31.1 weeks to 28.1 weeks for hip replacement, and 37.9 weeks to 31.4 weeks for knee replacement.

The percentage of patients receiving surgery within the benchmark was improved through the SEM in the literature. The proportion of patients receiving knee replacement surgery within the benchmark of 182 days increased from 43.2% to 49.1%.[48] The Joint Replacement Indicator report[57] indicated that 45% of patients through the Orthopedic Assessment Clinics in Nova Scotia received their hip and knee replacement surgery within the national benchmark of 182 days.

This study has not found the association between priority and WT2. Although there was a slight improvement in WT2 after implementing the SEM, high urgent levels (i.e. priority 1, priority 2) were not associated with a shorter WT2, compared to the low urgent level (priority 3). Before implementing the OCI clinic, the median WT2 in Eastern Health in 2010-2011 was 155 days for hip replacement and 234 days for knee replacement.[13] After implementing the OCI clinic, the median WT2 for a hip replacement was 133 days in priority 3, followed by 148 days in

priority 1, and 176 days in priority 2. Similarly, the median WT2 for knee replacement surgery was 178 days in priority 1, 214.5 days in priority 2, and 196 days in priority 3 from 2011 to 2019.

Our study found a considerable improvement in receiving surgery within benchmark of 182 days in priority 1 and priority 3 for hip and knee replacement surgery. The percentage of patients receiving surgery within 182 days was 58% for hip replacement and 39.5% for knee replacement in 2010-2011.[13] After implementing the SEM, the percentage of patients with priority 3 and priority 1 receiving hip replacement surgery within 182 days was 81.08% and 63.08%. Similarly, the percentage of the patients receiving knee replacement within 182 days was 50.86% in priority 1, and 45.23% in priority 3. The percentage of patients with priority 2 receiving surgery within 182 days was the lowest, with 52.33% for hip replacement and 41.78% for knee replacement.

Most patients in the study met MAWT and benchmarks, but the improvement in WT2 by priority was not improved. This can be explained by the large volume of referrals assigned a priority 2 in recent years. Moreover, clinical urgent ratings for hip and knee replacement surgery depend on criteria, including pain, stiffness, function, and others,[81,89] decided by orthopedic surgeons. Therefore, further studies need to explore the difference in urgent clinical scores by the OCI priority classification.

5.1.3. The improvement in total wait time

An improvement of TW for hip and knee replacement surgery through a SEM is limited to one study. Damani et al. (2019)[48] showed that Winnipeg Central Intake Service (WCIS) reduced total wait time from 43 weeks to 41.8 weeks for hip replacement and 56 weeks to 45.4 weeks for knee replacement.

In this study, implementation of the SEM has not improved TW. The 2006-2010 reports from the Fraser Institute[11,14-17] demonstrated that the median TW for orthopedic surgery in

Newfoundland ranged from 36.8 weeks (257.6 days) in 2006 to 62.4 weeks (436.8 days) in 2010. Our findings were higher than values of the Fraser Institute's reports. For hip replacement surgery, a TW was 269 days in priority 1, 315 days in priority 2, and 476 days in priority 3. For knee replacement surgery, a TW was 324.5 days in priority 1, 413 days in priority 2, and 719 days in priority 3. However, the use of values from the Fraser Insitute's reports should be used with caution because the Fraser Institute's reports were based on surveys with small sample sizes from 14 to 19 questionnaires mailed out to the province.[11,14-17]

Patients with knee replacement surgery had a longer TW than those with hip replacement surgery. Conner-Spady et al.[129] revealed that knee replacement patients accepted a longer maximum acceptable wait time by 2.8 weeks than hip replacement patients because knee replacement patients have a better ability to walk without significant pain and less potential disease progression. Our findings are consistent with studies that a TW for knee replacement is longer than that for hip replacement surgery by priority.

5.2. Factors impact the receiving consultation and surgery within the benchmarks for hip and knee replacement in the SEM

5.2.1. Factors impact the receiving consultation within benchmark of 90 days

In the literature, incomplete referral form might prolong WT1.[73,130,131] New referrals that were initially rejected increased WT1 by 8-46 business days.[73] Another study[130] revealed that WT1 was extended by 13%-36% in knee replacement patients due to incomplete referral form. The Alberta Hip and knee referral audit showed that an incomplete referral form prolonged WT1 up to 6 weeks.[131] Our study revealed that an incomplete referral form was more likely to prolong WT1 than completed referral from, but we have not found the association between incomplete initial referral forms and receiving consultation within 90 days.

Choosing to see the next available surgeon for consultation may shorten WT1.[70,73,132,133] Fyie et al.[73] identified that requesting a specific surgeon for consultation rather than the next available surgeon increased WT1 by 10-47 business days. However, many patients are unlikely to consider switching surgeons. Conner-Spady et al.[132] showed that 63% of patients with joint arthroplasty were unwilling to change surgeons. Marshall et al.[70] demonstrated that patients were willing to wait a long time to meet an excellent reputation before accepting the next available surgeon. Our findings showed that choosing the next available surgeon for hip replacement and for knee replacement allowed patients to see a surgeon for consultation sooner than requesting a specific surgeon. A patient choosing the next surgeon for knee replacement consultation was more likely to receive consultation within 90 days than a patient requesting a specific surgeon, while there was no association between patient's preference and receiving consultation within the benchmark for hip replacement surgery.

Osteoarthritis is the most common cause of total joint arthroplasty surgery.[128] This study found that a patient requiring knee replacement surgery due to osteoarthritis was less likely to receive consultation within 90 days than a patient needing knee replacement surgery due to other knee arthritis disorders such as rheumatoid arthritis. In contrast, we did not find an association between a hip replacement surgery due to osteoarthritis and receiving consultation within 90 days. In contrast to patients with rheumatoid arthritis that is best managed by a rheumatologist,[128,134] those with osteoarthritis will self-manage their disease by changing their lifestyles, using analgesics, or seeking healthcare professional treatments (e.g., family doctors, physiotherapist, occupational therapist)[128,135] before they were referred to secondary treatment (e.g., orthopedic surgeon, or rheumatologist).[128] Additionally, in comparation with patients with hip osteoarthritis referred for their total hip replacement surgery assessment, more percentage of patients with knee osteoarthritis (67%) did not have a total knee replacement surgery within 12 months because of

some reasons, including not desiring total knee replacement surgery, need to manage the disease by conservative treatments, requiring further monitoring, young age.[136]

This study explored an association between priority levels and receiving consultation within a benchmark of 90 days. Patients with priority 1 were the most likely to receive consultation within 90 days, followed by patients with priority 2 and priority 3 patient for both hip and knee replacement. Our study also revealed that patients whose referrals in 2014-2016 and 2017-2019 were more likely to receive consultation within 90 days than patients whose referrals in 2011-2013 although the volume of referrals in 2014-2016 and in 2017-2019 were larger than those in 2011-2013. It means that the use of prioritization in the OCI improved timely access to orthopedic surgeons for a consultation.

5.2.2. Factors impact the receiving a surgery within benchmark of 182 days

There are no studies in the literature that examined the association between WT2 and patient's preference for surgeon (the next available surgeon versus a specific surgeon). This study revealed that choosing the next available surgeon for consultation impacted on WT2. Patients who chose the next available surgeon were more likely to wait longer time to have a hip or knee replacement surgery than those requesting a specific surgeon. Additionally, patients choosing the next available surgeon were less like to have a hip or knee replacement surgery within 182 days. A lack of improving WT2 within 182 days when choosing next available surgeon may be due to an increase in the demand of patients requiring hip and knee replacement surgery in recent years and a lack of pooling surgeons for surgery. In fact, the number of referrals referred to the OCI clinic was the highest in 2014-2016 than in 2011-2013 and 2017-2019. Consequently, patients referred to the OCI clinic in 2014-2016 were less likely to have surgery within 182 days than those in 2011-2013 and 2017-2019. The SEM in Eastern Health improved the WT1 by pooling

surgeons and giving patients the choice of the next available surgeon for their consultation, but not for surgery. This meant that if a surgeon sees more patients for consultation, more patients have to wait for their surgery to be performed by that surgeon. In addition, the availability of other health providers and resources can influence how quickly patients have total joint replacement surgery.[137,138] The unavailability of human resources in the operation room or the unavailability of inpatient hospital beds for surgical patients may result in delaying elective surgeries.[137,138] Therefore, further research could look at whether or not providing the option of the next available surgeon for surgery through the SEM may improve WT2.

While the association between priority levels and receiving knee replacement surgery within 182 days was not established yet, more patients with priority 3 had hip replacement surgery within 182 days than patients with priority 1 in this study. Urgent clinical ratings for hip and knee replacement surgery depend on criteria, including pain, stiffness, function, and others,[76,84] decided by orthopedic surgeons. Damani et al. (2019)[43] found a significant association between receiving a hip replacement surgery within the benchmark and lower BMI and worse Oxford-12 score, and a significant association between receiving knee replacement surgery within the benchmark and worse Oxford-12 score. Priority classification in the OCI has worked for WT1 and TW, but not WT2. Patients with higher priority (priority 2 and priority 1) were less likely to receive surgeries sooner than those with lower priority (priority 3). Therefore, further studies need to explore why more patients with priority 3 are scheduled earlier than those with priority 1.

5.3. Implications of study findings

One of the main findings is that the SEM at the Eastern Health region of Newfoundland and Labrador improved wait time for consultation and the percentage of patients receiving

consultation within 90 days. A priority classification used through the SEM allowed patients with higher priority to be more likely to have a consultation booked sooner than their counterparts. Patients that chose the next-available surgeon had a chance to see a surgeon sooner than those requesting a specific surgeon. The family doctor is the gatekeeper to the specialist, and they will often make a choice in consultation with patients on how to refer. Therefore, how the referral process from GPs impacting patient's preferences should be evaluated in future research.

Despite improving timely access to consultation through the SEM, the chance to have surgery within the benchmark of 182 days by priority was mixed. While hip replacement patients with low priority were more likely to have surgery within 182 days than those with high priority, there is no significant difference in the chance to have surgery within 182 days among knee replacement patients by priority levels. This implied a difference in urgent clinical ratings between surgeon's perspectives and OCI priority classification.

Moreover, choosing the next available surgeon for consultation had a lower chance of receiving surgery within 182 than requesting a specific surgeon. This was a serious consideration when orthopedic surgeons were overburdened with large numbers of hip and knee replacement patients requiring surgery. Further strategies should allocate funding and resources such as operating rooms, inpatient hospital beds for surgical patients, and healthcare professional personnel that may delay elective surgeries. Eastern Health region should also focus on expanding the pool of participating surgeons for a consultation. New surgeons joining in the SEM can benefit by accepting new referrals when other surgeons are overburdened, thereby preventing the balance of waiting times across surgeons as the number of referrals choosing the next available surgeon increases. Another initiative is to develop a pool of participating surgeons for surgery. The SEM in Eastern Health gave patients the next available surgeon's choice for

consultation, but surgeons still manage their waiting list for surgery. As a result, they have to wait for surgery performed by that surgeon, even if another surgeon is available. With this strategy, the quality of care should be the same between patients choosing the next available surgeon and those requesting a specific surgeon for their surgery. Eastern Health should consider the conflict of interest probably occurring by choosing the next available surgeon for surgery.

Given the study's findings, qualitative research with all stakeholders, including health authorities, decision-makers, orthopedic surgeons, family doctors should be required to elucidate relevant factors that matter and significantly impact wait times as well as decision-making for treatment based on patient's perspectives and surgeon's perspectives through the SEM. Moreover, the SEM should be governed at the provincial level, not only at regional levels in order to improve wait times management, including tracking, measuring, and monitoring across regions. This can allow patients to have equity in accessing orthopedic services regardless of health regions and facilitate better sharing resources across health regions.

5.4. Strengths and limitations

This study provided an in-depth evaluation of the SEM and the priority classification to improve timely access to total joint arthroplasty in Newfoundland and Labrador's Eastern Health region using Orthopedic Central Intake's administrative data in Eastern Health. The administrative data allowed us to estimate WT1, WT2, and TW from referral to surgery with more accuracy than surveys. It is important to emphasize that wait times not only look at patients who have had surgery, but also all patients referred to the OCI. This study explored factors that significantly delayed having consultation or surgery in the SEM of the Eastern Health region from results of multivariable extended Cox proportional hazard regression models. The extended Cox proportional hazard regression models allowed us to evaluate time-varying covariates. By

using logistic regression models, the study also found the association the association between influential factors and the likelihood to receive a consultation and surgery within established benchmarks, including patient's preference for surgeon, priority levels, demands for hip and knee replacement surgery, and joint osteoarthritis, which have not been well-examined in literature.

Despite certain advantages, this study has certain limitations that must be acknowledge. We could not evaluate the improvement in WT1 prior to implementing OCI and after implementing OCI based on administrative data because WT1 and TW data before implementing the OCI clinic were not available. Therefore, we compared our findings with the Fraser Institute reports based on surveys with small sample sizes and low response rates, which may have been biased. Information regarding gender, and comorbidities, availability of resources is not available in the data sources in this study. Consequently, further research should examine which influential factors impact WT2 through the SEM in Eastern Health. However, our findings provide a partial picture of the SEM's benefits in improving timely access to hip and knee replacement services, which are not well-known yet from previous literature. The exclusion of large number of cases because of multiple referrals and because of not being in the TJAC database could reduce the representativeness of the sample and bias results. Future studies should look at the large number of cases not in the TJAC and examine why and how better to track their wait times (or if some of them are excluded because they do not progress to surgery - i.e. met with surgeon and decided no surgery is needed). Eastern Health should also take a closer look at patients with multiple referrals and see why this is happening, and how referral process can be improved.

5.5. Conclusion

This study demonstrates that a priority classification and a SEM could improve timely access to hip and knee replacement consultation services. Additionally, there was a significant relationship between WT1, TW, and priority level. However, we did not find an association between WT2 and priority levels. From our main findings and existing limitations in the study, we recommend that additional research is needed to explore more factors that impact wait times for hip and knee replacement surgery. Our findings provide essential information for patients and healthcare professionals in Eastern Health to understand the SEM's benefits to improve timely access to care in total joint arthroplasty.

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Appendix

Appendix A3-1: HREB approval for the study "Wait times in hip and knee replacement: Single entry model and prioritization"

NEWFOUNDLAND AND LABRADOR
HREB
HEALTH RESEARCH ETHICS BOARD

Research Ethics Office
Suite 200, Eastern Trust Building
95 Bonaventure Avenue
St. John's, NL
A1B 2X5

August 15, 2019

Division of Community Health and Humanities Faculty of Medicine
Memorial University of Newfoundland, St. John's, NL

Dear Vo Anh:

Researcher Portal File # 20200633
Reference # 2019.168

RE: Wait times in hip and knee replacement: Single entry model and prioritization

Your application was reviewed by a subcommittee under the direction of the HREB and the following decision was rendered:

X	Approval
	Approval subject to changes
	Rejection

Ethics approval is granted for one year effective August 15, 2019. This ethics approval will be reported to the board at the next scheduled HREB meeting.

This is to confirm that the HREB reviewed and approved or acknowledged the following documents (as indicated):

- Application approved
- Research Proposal approved
- Letter of Acknowledgement from Data Custodian approved
- Variable list approved

Please note the following:

- This ethics approval will lapse on August 15, 2020. It is your responsibility to ensure that the Ethics Renewal form is submitted prior to the renewal date.

Appendix A3-2: RPAC approval for the study "Wait times in hip and knee replacement: Single entry model and prioritization"

Eastern Health

Department of Research
5th Floor Janeway Hostel
Health Sciences Centre
300 Prince Philip Drive
St. John's, NL A1B 3V6
Tel: (709) 752-4636
Fax: (709) 752-3591

September 17, 2019

Ms. Anh Thu Vo
300 Prince Philip Drive
St. John's, NL
A1B 3V6

Dear Ms. Anh Thu Vo,

Your research proposal *HREB Reference #: 2019.168 "Wait times in hip and knee replacement: Single entry model and prioritization"* was reviewed by the Research Proposals Approval Committee (RPAC) of Eastern Health at a meeting dated September 10, 2019 and we are pleased to inform you that the proposal has been granted full approval.

The approval of this project is subject to the following conditions:

- The project is conducted as outlined in the HREB approved protocol;
- Adequate funding is secured to support the project;
- In the case of Health Records, efforts will be made to accommodate requests based upon available resources. If you require access to records that cannot be accommodated, then additional fees may be levied to cover the cost;
- A progress report being provided upon request.

If you have any questions or comments, please contact Krista Rideout, Manager of the Patient Research Centre at 777-7283 or by email at krista.rideout@easternhealth.ca.

Sincerely,

Farah McCrate
Farah McCrate
Regional Director, Research and Innovation
Co-Chair, RPAC

FM/rg

Appendix A3-3: The first HREB amendment approval for the study "Wait times in hip and knee replacement: Single entry model and prioritization"

MEMORIAL UNIVERSITY

Vo, Anh Thu Thi <attvo@mun.ca>

HREB - amendment (approved) 490652

4 messages

administrator@hrea.ca <administrator@hrea.ca> Fri, May 8, 2020 at 9:11 AM
To: "Vo Anh(Principal Investigator)" <attvo@mun.ca>
Cc: "Yi Yanqing(Supervisor)" <Yanqing.Yi@med.mun.ca>, administrator@hrea.ca

Researcher Portal File #: 20200633

Dear Anh Vo:

This e-mail is to inform you that your amendment event – Event No. 490652 - for study HREB # 2019.168 – Wait times in hip and knee replacement: Single entry model and prioritization - was reviewed by the Chair and has been approved and/or acknowledged (as indicated in the Researcher Portal).

You may view this decision by logging into the Researcher Portal.

It is your responsibility to seek the necessary organizational approval from the Regional Health Authority (RHA) or other organization as appropriate. You can refer to the HREA website for further guidance on organizational approvals.

Thank you,

Research Ethics Office

(e) info@hrea.ca
(t) 709-777-6974
(f) 709-777-8776
(w) www.hrea.ca
Office Hours: 8:30 a.m. – 4:30 p.m. (NL TIME) Monday-Friday

Vo, Anh Thu Thi <attvo@mun.ca> Fri, May 8, 2020 at 2:02 PM
To: RPAC <RPAC@easternhealth.ca>
Cc: Yanqing.Yi@med.mun.ca, Michelle Alexander <Michelle.Alexander@easternhealth.ca>, Marcel Billard <Marcel.Billard@easternhealth.ca>
Bcc: Anh Thu Thi Vo <attvo@mun.ca>

Dear RPAC,

Appendix A3-4: The second HREB amendment approval for the study "Wait times in hip and knee replacement: Single entry model and prioritization"

MEMORIAL UNIVERSITY

Vo, Anh Thu Thi <attvo@mun.ca>

2019 168 Amendment 502570 approved

4 messages

administrator@hrea.ca <administrator@hrea.ca> Thu, Jul 16, 2020 at 12:13 PM
To: "Vo Anh(Principal Investigator)" <attvo@mun.ca>
Cc: administrator@hrea.ca

Researcher Portal File #: 20200633

Dear Anh Vo:

This e-mail is to inform you that your amendment event # 50257 for study HREB # 2019.168 - Wait times in hip and knee replacement: Single entry model and prioritization - was reviewed by the Co-Chair on July 16, 2020 and has been approved and/or acknowledged (as indicated in the Researcher Portal). Event details are as follows:

Date event submitted: July 15, 2020

Approval/Acknowledgement of:

Questions		Answers
2.1	List ALL documents, including version dates, to be approved. Please upload these documents under the 'Attachments' tab.	1. Original HREB approval - August 15, 2019 2. Amendment HREB V1.0 - May 8, 2020 3. RPAC approval - September 17, 2019
2.2	Will there be any increase in risk, discomfort or inconvenience to the participants?	No
2.3	Please specify.	
2.4	Are there changes to inclusion or exclusion criteria?	No
2.5	Please specify.	
2.6	Are participants enrolled in the study at this site?	No
2.7	Is a modification to the consent form required?	No
2.8	Is a consent addendum required?	No
2.9	Please summarize the changes and provide the rationale for the significant changes being requested.	I are submitting an amendment application to changing data location. At this time, my de-identified data in which all identifiers were deleted are stored in the computer MED-1-018750 placed in the room M4M115 at the Medicine building, Memorial University. However, students cannot be allowed to access the office due to the COVID-19 pandemic, so our data analysis is postponed. Therefore, we will change the data location from the room M4M115 located in the Division of Community Health and Humanities to my current house so that I can continue my data analysis. The de-identified data will be moved From Division of Community Health and Humanities Faculty of Medicine Memorial University of Newfoundland St. John's, Newfoundland and Labrador Canada, A1B 3V6 To Truong Xuan Nguyen's house 299 Topsail Road St. John's, Newfoundland and Labrador Canada, A1E 2B4 Phone: 7097490990
2.10	If applicable, please describe how the information will be disseminated to participants enrolled in the study.	N/A

You may view this decision by logging into the Researcher Portal.

It is your responsibility to seek the necessary organizational approval from the Regional Health Authority (RHA) or other organization as appropriate. You can refer to the HREA website for further guidance on organizational approvals.

Thank you,

Research Ethics Office

(e) info@hrea.ca
(t) 709-777-6974
(f) 709-777-8776
(w) www.hrea.ca
Office Hours: 8:30 a.m. – 4:30 p.m. (NL TIME) Monday-Friday

Anh Thu Thi Vo <attvo@mun.ca> Thu, Jul 16, 2020 at 12:28 PM
To: "Yanqing.Yi@med.mun.ca" <Yanqing.Yi@med.mun.ca>

Appendix A3-5: The HREB renewal approval for the study "Wait times in hip and knee replacement: Single entry model and prioritization"

MEMORIAL UNIVERSITY

Vo, Anh Thu Thi <attvo@mun.ca>

HREB - Approval of Ethics Renewal 2019 168

2 messages

administrator@hrea.ca <administrator@hrea.ca> Thu, Jul 23, 2020 at 9:21 AM
To: "Vo Anh(Principal Investigator)" <attvo@mun.ca>
Cc: administrator@hrea.ca

Researcher Portal File #: 20200633

Dear Anh Vo:

This e-mail serves as notification that your ethics renewal for study HREB # 2019.168 – Wait times in hip and knee replacement: Single entry model and prioritization – has been **approved**. Please log in to the Researcher Portal to view the approved event.

Ethics approval for this project has been granted for a period of twelve months effective from 15 Aug 2020 to 15 Aug 2021.

Please note, it is the responsibility of the Principal Investigator (PI) to ensure that the Ethics Renewal form is submitted prior to the renewal date each year. Though the Research Ethics Office makes every effort to remind the PI of this responsibility, the PI may not receive a reminder. The Ethics Renewal form can be found on the Researcher Portal as an "Event".

The ethics renewal will be reported to the Health Research Ethics Board at their meeting dated 30 Jul 2020.

Thank you,

Research Ethics Office

(e) info@hrea.ca
(t) 709-777-6974
(f) 709-777-8776
(w) www.hrea.ca
Office Hours: 8:30 a.m. – 4:30 p.m. (NL TIME) Monday-Friday

Anh Thu Thi Vo <attvo@mun.ca> Thu, Jul 23, 2020 at 10:24 AM
To: "Yanqing.Yi@med.mun.ca" <Yanqing.Yi@med.mun.ca>
Cc: Maria Mathews <maria.mathews@schulich.uwo.ca>, Michelle Alexander <Michelle.Alexander@easternhealth.ca>

Appendix A3-6: The third HREB amendment approval for the study "Wait times in hip and knee replacement: Single entry model and prioritization"

MEMORIAL UNIVERSITY

Vo, Anh Thu Thi <attvo@mun.ca>

HREB - Event Decision (approved or acknowledged) 512653

1 message

administrator@hrea.ca <administrator@hrea.ca> Thu, Oct 29, 2020 at 3:41 PM
To: "Vo Anh(Principal Investigator)" <attvo@mun.ca>
Cc: "Yi Yanqing(Supervisor)" <yyi@mun.ca>, administrator@hrea.ca

Researcher Portal File #: 20200633

Dear Anh Vo:

This e-mail is to inform you that your amendment event – Event No. 512653 - for study HREB # 2019.168 – Wait times in hip and knee replacement: Single entry model and prioritization - was reviewed by the Chair and has been approved and/or acknowledged (as indicated in the Researcher Portal).
You may view this decision by logging into the Researcher Portal.

It is your responsibility to seek the necessary organizational approval from the Regional Health Authority (RHA) or other organization as appropriate. You can refer to the HREA website for further guidance on organizational approvals.

Thank you,

Research Ethics Office

(e) info@hrea.ca
(t) 709-777-6974
(f) 709-777-8776
(w) www.hrea.ca
Office Hours: 8:30 a.m. – 4:30 p.m. (NL TIME) Monday-Friday

Appendix A4-1: Stepwise selection procedure for the first model of **WT1 - hip replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Priority		2	1	231.1565		<.0001	Priority
2	Year of referral		2	2	168.8920		<.0001	
3	Initial referral		1	3	9.8550		0.0017	
4	Patient preference		1	4	7.0419		0.0080	
5	Diagnosis		1	5	1.7817		0.1819	Diagnosis
6		Diagnosis	1	4		1.7784	0.1823	Diagnosis

Appendix A4-2: Check Proportional hazards assumption for the first model of **WT1 - hip replacement**

Supremum Test for Proportionals Hazards Assumption				
Variable	**Maximum Absolute Value**	**Replications**	**Seed**	**Pr > MaxAbsVal[a]**
Patient preference	0.8526	1000	1297891323	0.3920
Initial referral	0.6621	1000	1297891323	0.6290
2011-2013	2.3276	1000	1297891323	0.0020
2014-2016	2.5311	1000	1297891323	<.0001
P2	3.4601	1000	1297891323	<.0001
P3	0.7038	1000	1297891323	0.6750

[a] Proportional hazards assumption is violated when p-value < 0.05

Appendix A4-3: Stepwise selection procedure for the second model of **WT1[a] - hip replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Priority		2	1	231.1565		<.0001	Priority
2	Year of referral		2	2	168.8920		<.0001	
3	Priority*WT1		1	3	27.0039		<.0001	
4	Patient preference		1	4	9.3502		0.0022	
5	Initial referral		1	5	6.3197		0.0119	
6	Year of referral*WT1		1	6	4.9464		0.0261	

[a] The second model of WT1 contain variables and their interaction with times if any variable was violated the proportional hazards assumption

Appendix A4-4: The final extended Cox-regression model of WT1 - hip replacement

Analysis of Maximum Likelihood Estimates										
Parameter		**DF**	**Parameter Estimate**	**Standard Error**	**Chi-Square**	**Pr > ChiSq**	**Hazard Ratio**	**95% Hazard Ratio Confidence Limits**		**Label**
Patient's preference	1	1	0.22328	0.08130	7.5421	0.0060	1.250	1.066	1.466	Patient's preference
Initial referral	1	1	-0.46830	0.18773	6.2227	0.0126	0.626	0.433	0.905	Initial referral
2011-2013	1	1	-1.11727	0.11649	91.9911	<.0001	0.327	0.260	0.411	2011-2013
2014-2016	2	1	0.05045	0.14717	0.1175	0.7318	1.052	0.788	1.403	2014-2016
P2	2	1	-1.82612	0.17363	110.6073	<.0001	0.161	0.115	0.226	P2
P3	3	1	-5.74873	0.53657	114.7877	<.0001	0.003	0.001	0.009	P3
Year of referral*WT1		1	-0.00175	0.0007868	4.9583	0.0260	0.998	0.997	1.000	
Priority*WT1		1	0.01174	0.00228	26.5668	<.0001	1.012	1.007	1.016	

Appendix A4-5: Stepwise selection procedure for the first model of **WT1 - knee replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Priority		2	1	627.5878		<.0001	Priority
2	Year of referral		2	2	68.7252		<.0001	
3	Patient preference		1	3	30.1861		<.0001	
4	Initial referral		1	4	6.5503		0.0105	
5	Diagnosis		1	5	1.9867		0.1587	Diagnosis
6		Diagnosis	1	4		1.9838	0.1590	Diagnosis

Appendix A4-6: Check Proportional hazards assumption for the first model of **WT1 - knee replacement**

Supremum Test for Proportionals Hazards Assumption				
Variable	**Maximum Absolute Value**	**Replications**	**Seed**	**Pr > MaxAbsVal[a]**
Patient preference	1.6490	1000	123445	0.0050
Initial referral	1.2053	1000	123445	0.0990
2011-2013	4.1944	1000	123445	<.0001
2014-2016	2.0339	1000	123445	0.0050
P2	3.7418	1000	123445	<.0001
P3	3.4212	1000	123445	<.0001

[a] Proportional hazards assumption is violated when p-value < 0.05

Appendix A4-7: Stepwise selection procedure for the second model of **WT1[a] - knee replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Priority		2	1	627.5878		<.0001	Priority
2	Year of referral		2	2	68.7252		<.0001	
3	Priority*WT1		1	3	48.9798		<.0001	
4	Patient preference		1	4	27.9736		<.0001	
5	Initial referral		1	5	5.0128		0.0252	

[a] The second model of WT1 contain variables and their interaction with times if any variable was violated the proportional hazards assumption

Appendix A4-8: The final extended Cox-regression model of WT1 - knee replacement

Analysis of Maximum Likelihood Estimates										
Parameter		**DF**	**Parameter Estimate**	**Standard Error**	**Chi-Square**	**Pr > ChiSq**	**Hazard Ratio**	**95% Hazard Ratio Confidence Limits**		**Label**
Patient's preference	**1**	1	0.34406	0.06523	27.8243	<.0001	1.411	1.241	1.603	Patient's preference
Initial referral	**1**	1	-0.29516	0.13043	5.1212	0.0236	0.744	0.576	0.961	Initial referral
2011-2013	**1**	1	-0.55381	0.08692	40.5935	<.0001	0.575	0.485	0.682	2011-2013
2014-2016	**2**	1	-0.04591	0.07567	0.3680	0.5441	0.955	0.823	1.108	2014-2016
P2	**2**	1	-1.70866	0.19214	79.0781	<.0001	0.181	0.124	0.264	P2
P3	**3**	1	-5.99723	0.47438	159.8270	<.0001	0.002	0.001	0.006	P3
Priority*WT1		1	0.01466	0.00216	45.9385	<.0001	1.015	1.010	1.019	

Appendix A4-9: Stepwise selection procedure for the first model of **WT2 - hip replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	Effect		DF	Number In	Score Chi-Square	Wald Chi-Square	Pr > ChiSq	Effect Label
	Entered	Removed						
1	Year of referral		2	1	28.2858		<.0001	
2	Diagnosis		1	2	6.4409		0.0112	Diagnosis
3	Patient preference		1	3	6.2693		0.0123	
4	Priority		2	4	4.3432		0.1140	Priority

Appendix A4-10: Check Proportional hazards assumption for the first model of **WT2 - hip replacement**

Supremum Test for Proportional Hazards Assumption				
Variable	Maximum Absolute Value	Replications	Seed	Pr > MaxAbsVal[a]
Diagnosis	0.7109	1000	12345	0.6080
Patient preference	1.4270	1000	12345	0.0280
2011-2013	2.5373	1000	12345	<.0001
2014-2016	1.9096	1000	12345	0.0080
Priority	1.0090	1000	12345	0.2

[a] Proportional hazards assumption is violated when p-value < 0.05

Appendix A4-11: Stepwise selection procedure for the second model of **WT2[a] - hip replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Year of referral		2	1	28.2858		<.0001	
2	Diagnosis		1	2	6.4409		0.0112	Diagnosis
3	Patient preference		1	3	6.2693		0.0123	
4	Patient preference*WT2		1	4	5.2850		0.0215	
5	Year of referral*WT2		1	5	4.6141		0.0317	

[a] The second model of WT2 contain variables and their interaction with times if any variable was violated the proportional hazards assumption

Appendix A4-12: The final extended Cox-regression model of WT2- hip replacement

Analysis of Maximum Likelihood Estimates										
Parameter		**DF**	**Parameter Estimate**	**Standard Error**	**Chi-Square**	**Pr > ChiSq**	**Hazard Ratio**	**95% Hazard Ratio Confidence Limits**		**Label**
Diagnosis	**1**	1	-0.25232	0.11184	5.0902	0.0241	0.777	0.624	0.967	Diagnosis
Patient's preference	**1**	1	-0.50601	0.14647	11.9357	0.0006	0.603	0.452	0.803	Patient's preference
2011-2013	**1**	1	-0.13594	0.11060	1.5106	0.2190	0.873	0.703	1.084	2011-2013
2014-2016	**2**	1	-0.73126	0.17524	17.4132	<.0001	0.481	0.341	0.679	2014-2016
Patient's preference*WT2		1	0.00168	0.0007019	5.7552	0.0164	1.002	1.000	1.003	
Year of referral*WT2		1	0.0009243	0.0004308	4.6039	0.0319	1.001	1.000	1.002	

Appendix A4-13: Stepwise selection procedure for the first model of **WT2 - knee replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Year of referral		2	1	47.6623		<.0001	
2	Patient preference		1	2	4.9183		0.0266	

Appendix A4-14: Check Proportional hazards assumption for the first model of **WT2 - knee replacement**

Supremum Test for Proportional Hazards Assumption				
Variable	**Maximum Absolute Value**	**Replications**	**Seed**	**Pr > MaxAbsVal[a]**
Patient preference	0.9346	1000	12345	0.3090
2011-2013	3.3465	1000	12345	<.0001
2014-2016	2.7813	1000	12345	<.0001

[a] Proportional hazards assumption is violated when p-value < 0.05

Appendix A4-15: Stepwise selection procedure for the second model of **WT2[a] - knee replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection						
Effect		DF	Number In	Score Chi-Square	Wald Chi-Square	Pr > ChiSq
Entered	Removed					
Year of referral		2	1	47.6623		<.0001
Year of referral*WT2		1	2	9.1263		0.0025
Patient preference		1	3	5.5515		0.0185

[a] The second model of WT2 contain variables and their interaction with times if any variable was violated the proportional hazards assumption

Appendix A4-16: The final extended Cox-regression model of WT2- knee replacement

Analysis of Maximum Likelihood Estimates										
Parameter		DF	Parameter Estimate	Standard Error	Chi-Square	Pr > ChiSq	Hazard Ratio	95% Hazard Ratio Confidence Limits		Label
Patient's preference	1	1	-0.14976	0.06349	5.5643	0.0183	0.861	0.760	0.975	Patient's preference
2011-2013	1	1	-0.43798	0.09540	21.0781	<.0001	0.645	0.535	0.778	2011-2013
2014-2016	2	1	-0.92733	0.15798	34.4573	<.0001	0.396	0.290	0.539	2014-2016
Year of referral*WT2		1	0.00109	0.0003503	9.6517	0.0019	1.001	1.000	1.002	

Appendix A4-17: Stepwise selection procedure for the first model of **TW- hip replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Year of referral		2	1	103.8992		<.0001	
2	Priority		2	2	14.3874		0.0008	PriorityID
3	Diagnosis		1	3	6.1296		0.0133	Diagnosis
4	Age group		1	4	4.4639		0.0346	

Appendix A4-18: Check Proportional hazards assumption for the first model of **TW - hip replacement**

Supremum Test for Proportionals Hazards Assumption				
Variable	**Maximum Absolute Value**	**Replications**	**Seed**	**Pr > MaxAbsVal[a]**
Age group	0.6636	1000	12345	0.7540
Diagnosis	0.6123	1000	12345	0.7910
P2	2.3364	1000	12345	<.0001
P3	1.5189	1000	12345	0.0330
2011-2013	2.1217	1000	12345	0.0040
2014-2016	1.8404	1000	12345	0.0140

[a] Proportional hazards assumption is violated when p-value < 0.05

Appendix A4-19: Stepwise selection procedure for the second model of **TW[a] - hip replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Year of referral		2	1	103.8992		<.0001	
2	Priority		2	2	14.3874		0.0008	Priority
3	Priority*TW		1	3	12.8933		0.0003	
4	Diagnosis		1	4	4.8005		0.0285	Diagnosis
5	Age group		1	5	5.8590		0.0155	
6	Year of referral*TW		1	6	1.6564		0.1981	
7		Year of referral*TW	1	5		1.6526	0.1986	

[a] The second model of TW contain variables and their interaction with times if any variable was violated the proportional hazards assumption

Appendix A4-20: The final extended Cox-regression model of TW- hip replacement

Analysis of Maximum Likelihood Estimates										
Parameter		**DF**	**Parameter Estimate**	**Standard Error**	**Chi-Square**	**Pr > ChiSq**	**Hazard Ratio**	**95% Hazard Ratio Confidence Limits**		**Label**
Age group	1	1	-0.17688	0.07302	5.8668	0.0154	0.838	0.726	0.967	Age group
Diagnosis	1	1	-0.28407	0.11594	6.0027	0.0143	0.753	0.600	0.945	Diagnosis
P2	2	1	-0.44122	0.11032	15.9951	<.0001	0.643	0.518	0.799	P2
P3	3	1	-1.17339	0.23053	25.9082	<.0001	0.309	0.197	0.486	P3
Priority*TW		1	0.0006601	0.0001884	12.2811	0.0005	1.001	1.000	1.001	
2011-2013	1	1	-0.86649	0.09807	78.0720	<.0001	0.420	0.347	0.510	2011-2013
2014-2016	2	1	-0.64236	0.08701	54.5056	<.0001	0.526	0.444	0.624	2014-2016

Appendix A4-21: Stepwise selection procedure for the first model of **TW- knee replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	Effect		DF	Number In	Score Chi-Square	Wald Chi-Square	Pr > ChiSq	Effect Label
	Entered	Removed						
1	Year of referral		2	1	281.6585		<.0001	
2	Priority		2	2	53.7657		<.0001	Priority
3	Age group		1	3	8.8605		0.0029	

Appendix A4-22: Check Proportional hazards assumption for the first model of **TW - knee replacement**

Supremum Test for Proportionals Hazards Assumption				
Variable	Maximum Absolute Value	Replications	Seed	Pr > MaxAbsVal[a]
Age group	1.1923	1000	12345	0.1280
2011-2013	3.2554	1000	12345	<.0001
2014-2016	2.9329	1000	12345	<.0001
P2	3.2199	1000	12345	<.0001
P3	5.2935	1000	12345	<.0001

[a] Proportional hazards assumption is violated when p-value < 0.05

Appendix A4-23: Stepwise selection procedure for the second model of **TW[a] - knee replacement** (sle=0.2 and sls=0.15)

Summary of Stepwise Selection								
Step	**Effect**		**DF**	**Number In**	**Score Chi-Square**	**Wald Chi-Square**	**Pr > ChiSq**	**Effect Label**
	Entered	**Removed**						
1	Year of referral		2	1	281.6585		<.0001	
2	Priority		2	2	53.7657		<.0001	Priority
3	Priority*TW		1	3	32.5508		<.0001	
4	Year of referral*TW		1	4	19.0010		<.0001	
5	Age group		1	5	10.7752		0.0010	

[a] The second model of TW contain variables and their interaction with times if any variable was violated the proportional hazards assumption

Appendix A4-24: The final extended Cox-regression model of TW- knee replacement

Analysis of Maximum Likelihood Estimates										
Parameter		**DF**	**Parameter Estimate**	**Standard Error**	**Chi-Square**	**Pr > ChiSq**	**Hazard Ratio**	**95% Hazard Ratio Confidence Limits**		**Label**
Age group	**1**	1	-0.19874	0.06045	10.8078	0.0010	0.820	0.728	0.923	Age group
2011-2013	**1**	1	-1.35347	0.09644	196.9440	<.0001	0.258	0.214	0.312	2011-2013
2014-2016	**2**	1	-1.51776	0.15892	91.2065	<.0001	0.219	0.161	0.299	2014-2016
P2	**2**	1	-0.78364	0.11773	44.3054	<.0001	0.457	0.363	0.575	P2
P3	**3**	1	-1.77000	0.19875	79.3124	<.0001	0.170	0.115	0.251	P3
Year of referral*TW		1	0.0007481	0.0001673	19.9976	<.0001	1.001	1.000	1.001	
Priority*TW		1	0.0009052	0.0001460	38.4178	<.0001	1.001	1.001	1.001	

Appendix A4-25: Check Goodness of fit in the multiple logistic regression model for the **receiving of consultation within 90 days - hip replacement**

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	**DF**	**Pr > ChiSq[a]**
15.9567	9	0.0678

[a] Model lack of fit when p-value <0.05

Appendix A4-26: Testing whether the area under the ROC curve differs from 0.5 (chance) - the multiple logistic regression model for the **receiving of consultation within 90 days - hip replacement**

ROC Contrast Test Results			
Contrast	**DF**	**Chi-Square**	**Pr > ChiSq[a]**
Reference = Model	1	67.5003	<.0001

[a] A significance difference from 0.5, p-value <0.05

Appendix A4-27: Check Goodness of fit in the multiple logistic regression model for the **receiving of consultation within 90 days - knee replacement**

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	**DF**	**Pr > ChiSq[a]**
10.0881	8	0.2589

[a] Model lack of fit when p-value <0.05

Appendix A4-28: Testing whether the area under the ROC curve differs from 0.5 (chance) - the multiple logistic regression model for the **receiving of consultation within 90 days - knee replacement**

ROC Contrast Test Results			
Contrast	**DF**	**Chi-Square**	**Pr > ChiSq[a]**
Reference = Model	1	586.6222	<.0001

[a] A significance difference from 0.5, p-value <0.05

Appendix A4-29: Check Goodness of fit in the multiple logistic regression model for the **receiving of surgery within 182 days - hip replacement**

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	**DF**	**Pr > ChiSq[a]**
4.8938	8	0.7689

[a] Model lack of fit when p-value <0.05

Appendix A4-30: Testing whether the area under the ROC curve differs from 0.5 (chance) - the multiple logistic regression model for the **receiving of surgery within 182 days - hip replacement**

ROC Contrast Test Results			
Contrast	**DF**	**Chi-Square**	**Pr > ChiSq[a]**
Reference = Model	1	53.3762	<.0001

[a] A significance difference from 0.5, p-value <0.05

Appendix A4-31: Check Goodness of fit in the multiple logistic regression model for the **receiving of surgery within 182 days - knee replacement**

Hosmer and Lemeshow Goodness-of-Fit Test		
Chi-Square	**DF**	**Pr > ChiSq[a]**
11.2741	7	0.1271

[a] Model lack of fit when p-value <0.05

Appendix A4-32: Testing whether the area under the ROC curve differs from 0.5 (chance) - the multiple logistic regression model for the **receiving of surgery within 182 days - knee replacement**

ROC Contrast Test Results			
Contrast	**DF**	**Chi-Square**	**Pr > ChiSq[a]**
Reference = Model	1	53.3762	<.0001

[a] A significance difference from 0.5, p-value <0.05

Appendix A4-33: Pearson Correlation Coefficients - Logistic regression model for **the receiving consultation within 90 days - hip replacement**

Pearson Correlation Coefficients, N = 806 Prob > |r| under H0: Rho=0							
	Benchmark	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Initial referral**	**Year of referral**	**Priority**
Benchmark	1.00000	-0.09033 0.0103	0.01671 0.6356	0.03184 0.3666	-0.09186 0.0091	-0.08099 0.0215	-0.35515 <.0001
Age group	-0.09033 0.0103	1.00000	-0.11515 0.0011	-0.00276 0.9377	0.05912 0.0935	0.06154 0.0808	0.12227 0.0005
Diagnosis	0.01671 0.6356	-0.11515 0.0011	1.00000	0.10600 0.0026	0.01304 0.7116	0.07868 0.0255	-0.06163 0.0804
Patient's preference for surgeon	0.03184 0.3666	-0.00276 0.9377	0.10600 0.0026	1.00000	-0.05697 0.1061	-0.06569 0.0623	0.04987 0.1572
Initial referral	-0.09186 0.0091	0.05912 0.0935	0.01304 0.7116	-0.05697 0.1061	1.00000	0.02495 0.4793	-0.04779 0.1753
Year of referral	-0.08099 0.0215	0.06154 0.0808	0.07868 0.0255	-0.06569 0.0623	0.02495 0.4793	1.00000	0.07282 0.0387
Priority	-0.35515 <.0001	0.12227 0.0005	-0.06163 0.0804	0.04987 0.1572	-0.04779 0.1753	0.07282 0.0387	1.00000

Appendix A4-34: Checking multicollinearity assumption - Logistic regression model for **the receiving consultation within 90 days - hip replacement**

Parameter Estimates								
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Tolerance**	**Variance Inflation**
Intercept	Intercept	**1**	1.24736	0.07583	16.45	<.0001	.	0
Age group		**1**	-0.03728	0.03189	-1.17	0.2428	0.96530	1.03595
Diagnosis		**1**	-0.01346	0.04995	-0.27	0.7877	0.96287	1.03856
Patient's preference for surgeon		**1**	0.04392	0.03512	1.25	0.2114	0.97634	1.02423
Initial referral		**1**	-0.25081	0.08024	-3.13	0.0018	0.98959	1.01051
Year of referral		**1**	-0.02656	0.01880	-1.41	0.1581	0.97722	1.02331
Priority	Priority	**1**	-0.30259	0.02835	-10.67	<.0001	0.97144	1.02940

Collinearity Diagnostics									
Number	**Eigenvalue**	**Condition Index**	**Proportion of Variation**						
			Intercept	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Initial referral**	**Year of referral**	**Priority**
1	4.84358	1.00000	0.00172	0.01259	0.00415	0.00901	0.00243	0.01134	0.00316
2	0.95588	2.25103	0.00009361	0.00048762	0.00025983	0.00284	0.97404	0.00039659	0.00034417
3	0.50852	3.08625	0.00096917	0.90818	0.01000	0.02274	0.00996	0.01584	0.00075947
4	0.36880	3.62400	0.00076887	0.00053258	0.00249	0.19373	0.00349	0.73665	0.00121
5	0.19215	5.02068	0.01716	0.01195	0.08953	0.74775	0.00374	0.22767	0.05061
6	0.10105	6.92321	0.00531	0.05632	0.55618	0.00011658	0.00267	0.00054514	0.37242
7	0.03002	12.70172	0.97397	0.00994	0.33739	0.02381	0.00366	0.00756	0.57149

Appendix A4-35: Pearson Correlation Coefficients - Logistic regression model **for the receiving consultation within 90 days - knee replacement**

Pearson Correlation Coefficients, N = 1153 Prob > |r| under H0: Rho=0							
	Benchmark	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Initial referral**	**Year of referral**	**Priority**
Benchmark	1.00000	-0.07709 0.0088	0.03486 0.2369	0.01009 0.7321	-0.07085 0.0161	-0.03329 0.2587	-0.46920 <.0001
Age group	-0.07709 0.0088	1.00000	-0.13404 <.0001	0.00884 0.7643	0.06829 0.0204	0.07922 0.0071	0.09625 0.0011
Diagnosis	0.03486 0.2369	-0.13404 <.0001	1.00000	-0.01724 0.5586	0.01940 0.5104	0.01554 0.5980	-0.11625 <.0001
Patient's preference for surgeon	0.01009 0.7321	0.00884 0.7643	-0.01724 0.5586	1.00000	-0.06676 0.0234	0.04194 0.1547	0.17200 <.0001
Initial referral	-0.07085 0.0161	0.06829 0.0204	0.01940 0.5104	-0.06676 0.0234	1.00000	-0.03109 0.2916	-0.03131 0.2881
Year of referral	-0.03329 0.2587	0.07922 0.0071	0.01554 0.5980	0.04194 0.1547	-0.03109 0.2916	1.00000	0.03174 0.2816
Priority	-0.46920 <.0001	0.09625 0.0011	-0.11625 <.0001	0.17200 <.0001	-0.03131 0.2881	0.03174 0.2816	1.00000

Appendix A4-36: Checking multicollinearity assumption - Logistic regression model for the **receiving consultation within 90 days - knee replacement**

Parameter Estimates								
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Tolerance**	**Variance Inflation**
Intercept	Intercept	**1**	1.39915	0.06935	20.18	<.0001	.	0
Age group		**1**	-0.02694	0.02629	-1.02	0.3057	0.96349	1.03790
Diagnosis		**1**	-0.03457	0.04140	-0.84	0.4038	0.96976	1.03119
Patient's preference for surgeon		**1**	0.09480	0.02790	3.40	0.0007	0.96540	1.03584
Initial referral		**1**	-0.16652	0.05505	-3.02	0.0025	0.98828	1.01186
Year of referral		**1**	-0.01351	0.01625	-0.83	0.4061	0.98971	1.01040
Priority	Priority	**1**	-0.42609	0.02320	-18.37	<.0001	0.95021	1.05240

Collinearity Diagnostics									
Number	**Eigenvalue**	**Condition Index**	**Proportion of Variation**						
			Intercept	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Initial referral**	**Year of referral**	**Priority**
1	4.92424	1.00000	0.00136	0.01206	0.00394	0.00979	0.00323	0.00992	0.00240
2	0.93871	2.29036	0.00007247	0.00069856	0.00019100	0.00491	0.96120	0.00241	0.00022214
3	0.47767	3.21076	0.00080246	0.89618	0.01006	0.04257	0.01621	0.00568	0.00101
4	0.31095	3.97945	0.00003342	0.01645	0.00154	0.46966	0.00076018	0.53769	0.00040407
5	0.23218	4.60530	0.01192	0.00312	0.12033	0.40277	0.01609	0.41424	0.01722
6	0.09224	7.30647	0.01415	0.05941	0.52444	0.06800	0.00025633	0.00740	0.33112
7	0.02401	14.32039	0.97166	0.01209	0.33950	0.00230	0.00226	0.02265	0.64763

Appendix A4-37: Pearson Correlation Coefficients - Logistic regression model for **the receiving surgery within 182 days - hip replacement**

Pearson Correlation Coefficients, N = 806 Prob > |r| under H0: Rho=0						
	Benchmark	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Year of referral**	**Priority**
Benchmark	1.00000	0.01818 0.6062	-0.05555 0.1150	-0.07766 0.0275	-0.14895 <.0001	0.02996 0.3957
Age group	0.01818 0.6062	1.00000	-0.11515 0.0011	-0.00276 0.9377	0.06154 0.0808	0.12227 0.0005
Diagnosis	-0.05555 0.1150	-0.11515 0.0011	1.00000	0.10600 0.0026	0.07868 0.0255	-0.06163 0.0804
Patient's preference for surgeon	-0.07766 0.0275	-0.00276 0.9377	0.10600 0.0026	1.00000	-0.06569 0.0623	0.04987 0.1572
Year of referral	-0.14895 <.0001	0.06154 0.0808	0.07868 0.0255	-0.06569 0.0623	1.00000	0.07282 0.0387
Priority	0.02996 0.3957	0.12227 0.0005	-0.06163 0.0804	0.04987 0.1572	0.07282 0.0387	1.00000

Appendix A4-38: Checking multicollinearity assumption - Logistic regression model for **the receiving surgery within 182 days - hip replacement**

Parameter Estimates								
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Tolerance**	**Variance Inflation**
Intercept	Intercept	**1**	0.70532	0.08340	8.46	<.0001	.	0
Age group		**1**	0.01901	0.03508	0.54	0.5881	0.96952	1.03144
Diagnosis		**1**	-0.04549	0.05505	-0.83	0.4089	0.96332	1.03808
Patient's preference for surgeon		**1**	-0.09557	0.03865	-2.47	0.0136	0.97928	1.02116
Year of referral		**1**	-0.09228	0.02072	-4.45	<.0001	0.97758	1.02293
Priority	Priority	**1**	0.03681	0.03120	1.18	0.2385	0.97416	1.02653

Collinearity Diagnostics								
Number	**Eigenvalue**	**Condition Index**	**Proportion of Variation**					
			Intercept	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Year of referral**	**Priority**
1	4.79531	1.00000	0.00176	0.01287	0.00425	0.00928	0.01159	0.00324
2	0.51095	3.06351	0.00101	0.90714	0.01009	0.02565	0.01477	0.00087322
3	0.36959	3.60203	0.00074832	0.00118	0.00232	0.19630	0.73352	0.00125
4	0.19273	4.98808	0.01725	0.01311	0.09046	0.74574	0.23182	0.04936
5	0.10130	6.88040	0.00529	0.05476	0.55139	0.00025041	0.00051983	0.37584
6	0.03013	12.61586	0.97395	0.01092	0.34150	0.02278	0.00778	0.56943

Appendix A4-39: Pearson Correlation Coefficients - Logistic regression model for **the receiving surgery within 182 days - knee replacement**

Pearson Correlation Coefficients, N = 1153 Prob > |r| under H0: Rho=0						
	Benchmark	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Year of referral**	**Priority**
Benchmark	1.00000	-0.07709 0.0088	0.03486 0.2369	0.01009 0.7321	-0.03329 0.2587	-0.46920 <.0001
Age group	-0.07709 0.0088	1.00000	-0.13404 <.0001	0.00884 0.7643	0.07922 0.0071	0.09625 0.0011
Diagnosis	0.03486 0.2369	-0.13404 <.0001	1.00000	-0.01724 0.5586	0.01554 0.5980	-0.11625 <.0001
Patient's preference for surgeon	0.01009 0.7321	0.00884 0.7643	-0.01724 0.5586	1.00000	0.04194 0.1547	0.17200 <.0001
Year of referral	-0.03329 0.2587	0.07922 0.0071	0.01554 0.5980	0.04194 0.1547	1.00000	0.03174 0.2816
Priority	-0.46920 <.0001	0.09625 0.0011	-0.11625 <.0001	0.17200 <.0001	0.03174 0.2816	1.00000

Appendix A4-40: Checking multicollinearity assumption - Logistic regression model for **the receiving surgery within 182 days - knee replacement**

Parameter Estimates								
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Tolerance**	**Variance Inflation**
Intercept	Intercept	**1**	1.38624	0.06946	19.96	<.0001	.	0
Age group		**1**	-0.03302	0.02631	-1.26	0.2097	0.96915	1.03183
Diagnosis		**1**	-0.03785	0.04153	-0.91	0.3622	0.97042	1.03048
Patient's preference for surgeon		**1**	0.09992	0.02795	3.58	0.0004	0.96897	1.03202
Year of referral		**1**	-0.01182	0.01630	-0.73	0.4685	0.99088	1.00921
Priority	Priority	**1**	-0.42444	0.02327	-18.24	<.0001	0.95074	1.05181

Collinearity Diagnostics								
Number	**Eigenvalue**	**Condition Index**	**Proportion of Variation**					
			Intercept	**Age group**	**Diagnosis**	**Patient's preference for surgeon**	**Year of referral**	**Priority**
1	4.85593	1.00000	0.00141	0.01243	0.00406	0.01020	0.01028	0.00247
2	0.48161	3.17531	0.00079057	0.89204	0.00964	0.04868	0.00693	0.00106
3	0.31112	3.95071	0.00004398	0.01815	0.00177	0.47776	0.53005	0.00037774
4	0.23501	4.54564	0.01181	0.00529	0.11916	0.39219	0.42300	0.01654
5	0.09226	7.25479	0.01423	0.05904	0.52300	0.06916	0.00758	0.33202
6	0.02406	14.20512	0.97172	0.01304	0.34236	0.00201	0.02216	0.64753