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DEVIATIONS IN FAST TRACK TOTAL JOINT ARTHROPLASTY

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ACADEMIC DISSERTATION

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”I would rather have questions that can’t be answered than answers that can’t be questioned”

\- Richard Feynman

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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications:

I **Saku SA, Linko R, Madanat R.** Outcomes of Triggering the Emergency Response Team at a High-Volume Arthroplasty Center. *Scand J Surg. 2019. DOI: 10.1177/1457496919857263. (Ahead of print).*

II **Saku SA, Mäkinen TJ, Madanat R.** Reasons and Risk Factors for Delayed Discharge After Total Knee Arthroplasty Using an Opioid-Sparing Discharge Protocol. *J Arthroplasty. 2019;34(10):2365-70.*

III **Hällfors E, Saku SA, Mäkinen TJ, Madanat R.** A Consultation Phone Service for Patients With Total Joint Arthroplasty May Reduce Unnecessary Emergency Department Visits. *J Arthroplasty. 2018;33(3):650-54.*

IV **Saku SA, Mäkinen TJ, Madanat R.** Reasons and risk factors for ninety day re-admission following primary total knee arthroplasty in a high-volume centre. *Int orthop. 2018;42(1):95-99.*

These publications are referred to in the text by their Roman numerals. The articles have been reprinted with the permission of their copyright holders.

ABSTRACT

Total joint arthroplasty (TJA) is the gold-standard treatment for severe hip and knee osteoarthritis. In recent decades, the hospital length of stay (LOS) has reduced substantially largely due to the widespread implementation of fast track protocols. Although the results are now better than ever and most patients have joint replacement without complications, some patients experience one or several deviations from the fast track protocol. In healthcare systems similar to those in Finland, knowledge on these deviations is sparse. This doctoral thesis sought to elucidate some of the deviations in TJA in a Finnish healthcare system.

The study population consisted of TJA (i.e. total hip arthroplasty [THA] and total knee arthroplasty [TKA]) patients that underwent surgery at Helsinki University Hospital between 2014 and 2017. The study aimed to identify the reasons and risk factors for delayed discharge and 90-day readmissions after primary TKA. The study also aimed to assess early postoperative emergencies by evaluating the use of an Emergency Response Team (ERT) in the arthroplasty ward. Lastly, the study aimed to evaluate a novel phone consultation service for TJA patients and thereby elucidate common post-discharge concerns.

The median LOS after TKA was 3 days. The main reasons for delayed discharge were related to functional recovery and pain. Risk factors for a discharge after the third postoperative day were older age, higher American Society of Anaesthesiologists (ASA) score, shorter preoperative walking distance, general anaesthesia, longer duration of surgery, longer time spent in Post-Anaesthesia Care Unit, and surgery later in the week.

The 90-day readmission rate was 8.0% after primary TKA. The most common reasons for readmission were surgical site infection and knee pain. Independent predictors of readmission were psychiatric disease, asthma, a preoperative valgus malalignment, and a preoperative knee flexion deficit.

The rate of ERT calls was approximately 7 per 1000 admissions. The most common criteria that triggered the ERT call were decreased level of consciousness, hypotension, and low oxygen saturation. Half of the patients could be treated at the ward after ERT intervention, and the other half was moved to the Intensive Care Unit. Common causes of the emergency included drug-related side effects, pneumonia, and pulmonary embolism.

Concerns regarding prescribed medication, wound problems, and mobilization triggered most of the phone consultation service calls. The answering nurse alone resolved two thirds of all calls. Thirteen percent of the patients received instructions to visit the Emergency Department (ED) and half of them had a condition requiring treatment. Only two patients (0.7%) that should have been directed to the ED did not receive such instructions.

This study identified several new risk factors for deviations in TJA. Due to the single-payer healthcare system, the possible confounding effect of insurance status did not confound the results. Despite differences in healthcare systems,

both LOS and the readmission rate were similar to those previously reported. Considering the present study, a phone consultation service seems to reduce the amount of unnecessary ED visits. Employing an ERT service likely reduces the amount of ICU admissions after TJA surgery.

TIIVISTELMÄ

Tekonivelleikkaus on pitkälle edenneen polven ja lonkan nivelrikon ensisijainen hoitomuoto. Viimeisten vuosikymmenten aikana hoitoajat ovat lyhentyneet huomattavasti ns. fast track -hoitoketjun avulla. Vaikka tulokset ovat laajalti parantuneet, ja suurin osa potilaista kotiutuu viimeistään kolmantena leikkauksen jälkeisenä päivänä, ilmenee osalle potilaista yksi tai useampi poikkeama hoitoketjussa. Näistä poikkeamista tiedetään hyvin vähän Suomen kaltaisessa terveydenhuoltojärjestelmässä. Tämän tutkimuksen tarkoituksena oli selvittää syitä usealle yleiselle poikkeamalle polven ja lonkan tekonivelleikkauksen jälkeen.

Tutkimus koostui vuosien 2014 ja 2017 välillä Helsingin yliopistollisessa keskussairaalassa tehdyistä polven ja lonkan tekonivelleikkauksista. Tutkimuksen tavoitteena oli selvittää syyt ja riskitekijät myöhästyneelle kotiutumiselle ja osastolle uudelleen joutumiselle. Toisena tavoitteena oli arvioida hätäryhmän (Emergency Response Team, ERT) toimintaa tekonivelosastolla. Tämän lisäksi tutkimuksessa arvioitiin tekonivelpotilaiden puhelinpalvelun toimivuutta ja selvitettiin yleisimmät huolenaiheet kotiutumisen jälkeen.

Hoitojakson mediaanipituus polven ensitekonivelleikkauksen jälkeen oli kolme päivää. Yleisimmät syyt kotiutumisen viivästymiselle olivat hidas mobilisaatio ja kipu. Riskitekijöitä kotiutumisen viivästymiselle olivat korkea ikä, korkea ASA-luokka, lyhentynyt kävelymatka ennen leikkausta, yleisanestesia, pidempi leikkaus, pidempi vietetty aika heräämössä sekä leikkaus viikon loppupuolella.

Kahdeksan prosenttia potilaista joutui uudelleen osastolle yhdeksänkymmenen päivän kuluessa polven tekonivelleikkauksesta. Yleisimmät syyt olivat leikkausalueen infektio ja polvikipu. Riskitekijöitä osastolle uudelleen joutumiselle olivat psyykkinen sairaus, astma, valgus-virheasento sekä polven koukistusvajaus.

ERT-hälytyksiä oli noin seitsemän tuhatta potilasta kohden. Yleisimmät hälytyksen laukaisevat kriteerit olivat tajunnantason lasku, matala verenpaine ja huono hapettuminen. Puolet potilaista pystyttiin hoitamaan osastolla ERT-ryhmän intervention jälkeen, ja puolet potilaista jouduttiin siirtämään tehovalvontaosastolle. Yleisimmät syyt potilaan tilan äkilliselle romahtamiselle olivat lääkkeen sivuvaikutus, keuhkokuume ja keuhkoveritulppa.

Epäselvyydet reseptilääkkeiden käytöstä, haavaongelmat ja mobilisaatioon liittyvät ongelmat olivat yleisimmät syyt, jotka johtivat yhteydenottoon tekonivelpotilaiden puhelinpalveluun. Hieman yli kahdessa kolmasosassa puheluista huolenaihe ratkesi hoitajan antamien ohjeiden avulla. Kolmetoista prosenttia potilaista ohjeistettiin käymään päivystyksessä, ja puolet heistä sai hoitoa vaativan diagnoosin. Ainoastaan kaksi potilasta (0.7%), joiden olisi pitänyt hakeutua päivystykseen, eivät saaneet ohjeita hakeutua sinne.

Tässä tutkimuksessa tunnistettiin useita uusia riskitekijöitä, jotka altistavat poikkeamille tekonivelleikkauksen hoitoketjussa. Sekä hoitojakson pituus että osastolle uudelleen joutumisen riski olivat kansainvälisiin tuloksiin verrattuna samankaltaisia, vaikka terveydenhuoltojärjestelmien välillä on suuria eroja. Tämän tutkimuksen valossa tekonivelpotilaille tarkoitettu puhelinpalvelu on hyvä tapa hoitaa leikkauksen jälkeisiä huolia, ja se todennäköisesti estää turhia päivystyskäyntejä. ERT-ryhmä näyttäisi vähentävän tehohoidon tarvetta tekonivelleikkauksen jälkeen.

ABBREVIATIONS

ACRR	all-cause readmission rate
ASA	American Society of Anaesthesiologists
BMI	Body Mass Index
CCI	Charlson Comorbidity Index
CI	confidence interval
DVT	deep vein thrombosis
ED	emergency department
ERAS	Enhanced Recovery After Surgery protocol
ERT	Emergency Response Team
GA	general anaesthesia
GP	general practitioner
ICD-9	International Classification of Diseases, 9^{th} version
ICU	intensive care unit
IMC	intermediate care unit
IQR	interquartile range
KS	knee society
KSS	Knee Society Score
LIA	local infiltration analgesia
LOS	length of (hospital) stay
LUIC	length of uninterrupted institutional care
MCID	minimal clinically important difference
MUA	manipulation under anaesthesia
NPS	net promoter score
NSAID	non-steroidal anti-inflammatory drug
OA	osteoarthritis
OARA	Outpatient Arthroplasty Risk Assessment score
OR	odds ratio
PASS	patient acceptable symptom state
PE	pulmonary embolism
PJI	prosthetic joint infection
PT	physiotherapy
PROM	patient reported outcome measure
PREM	patient reported experience measure
RTT	return to theatre
SES	socioeconomical status
SSI	surgical site infection
TJA	total joint arthroplasty
THA	total hip arthroplasty
TKA	total knee arthroplasty

1. INTRODUCTION

Total joint arthroplasty (TJA) is the gold-standard of treatment for severe hip and knee osteoarthritis (OA). In this thesis, and generally in the field of lower limb arthroplasty, the term TJA refers to total hip arthroplasty (THA) and total knee arthroplasty (TKA) together. Although much has changed since the first hip replacements in the early 1960s, the main objective remains the same—to remove and replace worn-down joints with an artificial surface, most often consisting of a metal on polyethylene bearing. Implant durability has improved considerably and is no longer considered one of the most important areas for future improvement. Instead, much effort is focused making the entire joint replacement process more streamlined, mainly to shorten the hospital stay, save resources, and improve outcomes. Just a couple of decades ago, patients stayed in the hospital for several weeks following TJA. Today, TJA is even performed as an outpatient procedure in selected patients, with the patient being discharged on the day of surgery.

The number of TJAs is continuously rising and the demand is expected to grow further in the future. This is mainly due to an aging population, increasing obesity, and broader indications. The increasing demand together with an ever more stretched healthcare budget calls for increased cost-awareness and process optimization in every way possible.

One important factor affecting the cost of TJA is the number of days spent in hospital. Reducing the hospital length of stay (LOS) is a win-win situation. Patients with lower LOS are more satisfied, they have fewer or equal amounts of complications, and the total cost is usually lower. Recently, hospitals in healthcare systems with pay-for-performance reimbursement models have been forced to care for the patient not only during the initial hospital stay, but also for a short period of time after the patient is discharged without reimbursement for possible unplanned care episodes. If the quality of care is inadequate, the patient is more likely to develop a postoperative complication (e.g. surgical site infection) and must return to the hospital, thus increasing the costs for the hospital. This has increased interest in readmission rates, mostly during the first 30 and 90 days after discharge, as a quality measure. Readmitted patients often require extensive resources, sometimes even additional surgery, which makes readmissions very expensive.

Because of the value-driven and pay-for-performance healthcare system in the United States (US), these topics have received most attention there. This has led to most studies being performed in US hospitals, where the healthcare system is rather different from that in Europe, especially compared to the Nordic countries. Although the hospitals in the Nordics are not (yet) being punished financially for poor outcomes, it is still important to continuously strive for improvement, to avoid wasting resources, and to improve the quality of care. As most studies have been performed in the US, they are not directly applicable to the Finnish healthcare system. Until now, little has been known about which factors affect readmissions and LOS in a European healthcare system. It is not clear if we face different challenges or if we have the same problems despite differences in healthcare systems.

All deviations from a standard postoperative path increase morbidity and costs. This study was initiated to investigate some of the most common deviations in TJA in a Finnish hospital. The first study examined early postoperative emergencies where the Emergency Response Team (ERT) was engaged. The second study assessed the reasons and risk factors for prolonged LOS after TKA. The third study evaluated a phone consultation service, which was initiated to handle post-discharge concerns among TJA patients. The fourth and last study investigated the rates, reasons, and risk factors for unplanned readmission after TKA. A schematic timeline of these deviations is shown in **Figure 1**.

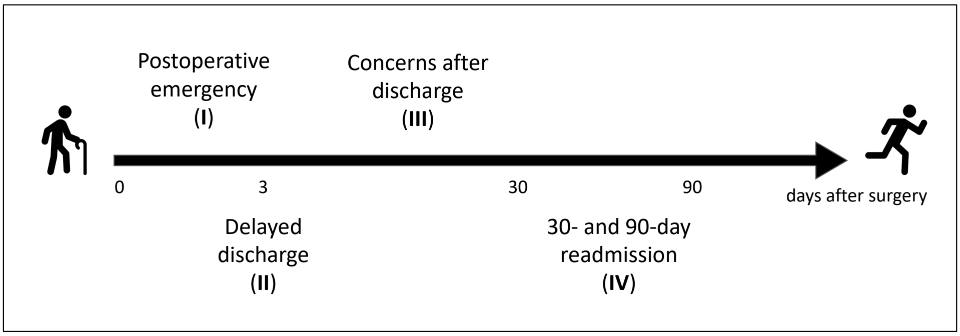

Figure 1. Timeline of deviations in TJA investigated in this thesis.

2. REVIEW OF THE LITERATURE

2.1 FAST TRACK PROTOCOL

Fast track protocols were first introduced in the mid-1990s (Kehlet and Wilmore 2008). Fast track is concerned with optimizing every aspect of care (pre-, peri-, and post-operatively) with the ultimate goal of reducing LOS without compromising quality of care. The whole surgical process can be viewed as an assembly line, where many different aspects must work in concert for the line to be as effective as possible. Modern fast track surgery is a team process that involves not only the surgeon and the surgical team, but also physiotherapists, anaesthesiologists, nurses, and social workers.

2.1.1 Pre-operative optimization

The pre-operative optimization starts with pre-operative clinical assessments and patient education lectures (Husted and Holm 2006). The goal is to inform the patient on what the TJA process entails and to set expectations on pain levels, post-operative function, and LOS. By optimizing certain comorbidities, the associated risks can be decreased. For example, optimizing glycaemic control in diabetes lowers the risk of surgical site infection (Iorio and Osmani 2017). Smoking cessation is known to improve wound healing and lowers the risk of post-operative complications (Iorio and Osmani 2017). Alcohol does not affect the outcomes as much as smoking, although there seems to be some correlation between alcohol consumption and complications (Best et al. 2015).

A higher use of opioids pre-operatively has been linked to poorer outcomes (Sing et al. 2016) and may be a subject for intervention. Malnutrition and severe obesity are also factors that can be optimized when planning the surgery.

Other areas of pre-operative optimization include dental exams, nasal colonisation screening, and laboratory tests to identify, for example, anaemia.

2.1.2 Peri-operative optimization

Peri-operative optimization consists of planning the surgical schedule, choosing between general or spinal anaesthesia, and ensuring availability of physiotherapy (PT) immediately after the surgery. There is currently little evidence that the surgical approach affects the early complication rates (Miller et al. 2018). Robot-assisted surgery is one interesting area of possible future peri-operative improvement, but the results are not yet good enough to compensate for the higher cost (Jacofsky and Allen 2016).

A multimodal pain management protocol, with the target to reduce opioid use, has lately received considerable attention. Multimodal pain regimens usually consist of paracetamol, non-steroidal anti-inflammatory drugs (NSAIDs), local infiltration analgesia (LIA), weak opioids, and short-acting stronger opioids for breakthrough pain (Husted 2012). Sometimes, corticosteroids and gabapentinoids are also included. Cryotherapy and other non-medical pain-relieving regimens may also be used.

Postoperative thromboprophylaxis consisting of both pharmacologic agents and mechanical compression devices is generally recommended (American Academy of Orthopaedic Surgeons 2011). There is, however, no clear consensus regarding the type, dose, and duration of pharmacologic prophylaxis. The Finnish Arthroplasty Association recommends using pharmacologic thromboprophylaxis for 10–14 days after TKA and 28–35 days after THA (The Finnish Arthroplasty Association 2015). Interestingly, a recent study suggests that anti-thrombotic treatment in selected patients may be needed only during the hospital stay (Petersen et al. 2018).

In a modern fast track protocol, mobilization starts on the day of surgery, just hours after the procedure. Intensive training with a physiotherapist is usually provided several times a day until discharge and is fundamental for early rehabilitation and rapid discharge.

2.2 EPIDEMIOLOGY

The demand for both hip and knee arthroplasty is rising worldwide, mostly due to an aging population and the obesity epidemic. Currently, more than 100 000 TKAs are performed each year in the United Kingdom (UK) and over 700 000 are performed in the United States (US) (Price et al. 2018). Projections from 2007 estimate that the demand for primary TKA will grow by almost 700% from the year 2005 to 2030 in the US (Kurtz et al. 2007).

More than a million total hip arthroplasties (THA) are performed worldwide every year (Pivec et al. 2012). The number of THAs is expected to increase by nearly 200% in the US from 2005 to 2030 (Kurtz et al. 2007). The lifetime risk of undergoing TKA surgery in UK is approximately 10%, with women needing a knee replacement more often than men (Price et al. 2018). In 2010, the prevalence for THA was 0.8% and 1.5% for TKA in the US (Kremers et al. 2014). At 80 years of age, the prevalence rose to 5.3% for THA and 10.4% for TKA.

An Australian study projects an 140% increase in TKA and a 220% increase in THA volumes from 2014 to 2046 (Inacio et al. 2017). The seemingly ever increasing demand for TJA highlights the need for continuous quality improvement to reduce the complication burden and increase cost effectiveness.

Nearly 11 000 patients undergo THA surgery in Finland annually. The trend is steadily rising and the numbers have doubled since the year 2000. The number of revision THAs has seen a slight decrease in the last 5 years; approximately 2000 revisions are now performed annually. The utilization rate is approximately 400 per 100 000 inhabitants aged ≥40 years (Finnish Arthroplasty Register, https://www.thl.fi/far/#index). In Finland, the lifetime risk of undergoing THA surgery was 15% for females and 11% for males in 2013 (Ackerman et al. 2017b).

TKA is somewhat more common in Finland than THA, with an annual number of approximately 13 000. The annual amount of TKAs has doubled since the year 2000. Approximately 1200 patients undergo revision TKA surgery each year. The number of revision surgeries has remained stable during the last 10 years. (Finnish Arthroplasty Register, https://www.thl.fi/far/#index). The lifetime risk of undergoing TKA was 23% for females and 12% for males in 2013 (Ackerman et al. 2017a).

2.3 EARLY POSTOPERATIVE COMPLICATIONS

2.3.1 Major postoperative adverse events

Although TJA (i.e. TKA or THA) is generally regarded as a safe procedure, joint replacements are major surgeries with inherent risks. Between 3% to 7% of TJA patients require critical care intervention after surgery (Memtsoudis et al. 2012, Courtney et al. 2015). Between 2% to 5% of TJA patients experience a major adverse event; greater age is the most important risk factor (Memtsoudis et al. 2007). Other proposed risk factors for requiring critical care interventions include congestive heart failure, chronic obstructive pulmonary disease, intra-operative blood loss >1000 ml, intra-operative use of vasopressors, revision surgery, and high Body Mass Index (BMI) (Courtney et al. 2015). General anaesthesia (GA) is also associated with a higher use of critical care services compared with spinal anaesthesia (Memtsoudis et al. 2012). There is conflicting evidence whether TKA or THA carries a greater risk for major complications (Pulido et al. 2008, Memtsoudis et al. 2012).

The most common major complications after TJA are surgical site infection, pneumonia, deep vein thrombosis, pulmonary embolism, myocardial infarction, tachyarrhythmia, and stroke (Memtsoudis et al. 2007, Pulido et al. 2008).

2.3.2 Emergency response teams

The objective of Emergency Response Teams (ERT) is to improve the management of patients whose condition is rapidly deteriorating. Particularly among the surgical patient population, ERT intervention appears beneficial with regard to postoperative adverse events and mortality (Bellomo et al. 2004, McNeill and Bryden 2013). In surgical patients, the use of an ERT service also seems to reduce long-term mortality (Jones et al. 2007). Furthermore, in one study, the introduction of an ERT service led to a significant reduction in unplanned ICU admissions (Dacey et al. 2007).

There are several terms for the same kind of service that provide acute intervention to deteriorating ward patients. The most commonly used terms are

ERT, Medical Emergency Team (MET) (Baxter et al. 2008), Rapid Response Team (Chan et al. 2010), and Intensive Care Team (Lee et al. 1998).

An ERT usually consists of one or two nurses specialised in critical care medicine and one anaesthesiologist or intensivist (Bellomo et al. 2004, Baxter et al. 2008). The ERT is usually based in the hospital's intensive care unit (ICU), where the members of the team participate in the daily care of ICU patients. The ERT service also includes training for the nursing staff at the ward on how and when to make an ERT call. The ERT call is made either with a pager, through the hospital loudspeaker system, or by phone. The call is made by anyone in the healthcare team when at least one of several vital parameter-based criteria is met, or whenever a healthcare worker is acutely worried about the patient's condition. The ERT members bring with them drugs and equipment commonly used in resuscitation situations that are not always available in the ward (Bellomo et al. 2004, Jones et al. 2007).

The rate of ERT calls in mixed patient populations varies from 8 to 40 calls per 1000 hospital admissions (Baxter et al. 2008, Silva et al. 2016). One study on surgical patients investigated ERT activations within 48 hours after surgery and revealed an ERT call rate of 2 calls per 1 000 surgeries (Weingarten et al. 2012). Medical patients contribute significantly more to ERT activations than surgical patients (Silva et al. 2016). ERT interventions are mostly related to airway and breathing support, fluid resuscitation, and medication adjustments.

In a study including both surgical and medical patients, airway threatening, concern of medical staff, and decreased consciousness most commonly triggered the ERT (Silva et al. 2016). Young and colleagues (2008) reported that hypotension was the most common ERT trigger.

In a recent study, a UK hospital introduced an automated vital parameter-based notification system that automatically activates the ERT based on similar criteria as in traditional ERT systems. Although the automated system led to a somewhat higher number of ERT activations, superior outcomes were observed compared to traditional "manual" patient supervision and activation (Subbe et al. 2017).

2.3.3 Intensive care unit admission after TJA

Some patients require further care in the ICU following an adverse event and a possible ERT activation. ICU admission rates after TJA vary considerably. Values ranging from 0.6% (AbdelSalam et al. 2012), 1.4% (Baumgartner et al. 2018) and 8.6% (Klausing et al. 2019) have been reported, although the latter study included both ICU and intermediate care unit (IMCU) admissions.

Risk factors for ICU admission after TJA include smoking, cemented arthroplasty, general anaesthesia, higher BMI, higher age, lower preoperative haemoglobin level, higher preoperative C-reactive protein (CRP) levels, and a need for blood transfusion (AbdelSalam et al. 2012).

Kamath and colleagues (2012) evaluated a system for triaging THA patients to either the ward or ICU directly postoperatively based on a risk score that uses preoperatively available variables. The triage system reduced the rates of both unplanned ICU admissions (from 7% to 2%) and complications (from 13% to 2%). The total number of ICU admissions increased only modestly and the average LOS in the ICU decreased by approximately 30%.

The literature lacks information on reasons for ICU admission after TJA.

2.4 LENGTH OF HOSPITAL STAY AFTER PRIMARY TJA

LOS usually refers to the number of postoperative nights spent in hospital (Husted et al. 2012). Authors sometimes also choose to report the length of uninterrupted institutional care (LUIC) (Pamilo et al. 2018). In this case, the LOS of possible further admissions to rehabilitation institutions or other hospitals are added to the primary LOS.

LOS after primary TJA has been reduced from almost 2 weeks about 20 years ago to a median of 2 or 3 days currently (Husted et al. 2012, Featherall et al. 2018). LOS has also decreased significantly during the last 10 years and is still decreasing (Grosso et al. 2019). The reported LOS varies considerably not only between countries but also between hospitals within the same country or region. **Table 1** shows reported average LOS in the most recent studies from different parts of the world. The hospitals with the lowest reported LOS seem to have an average of approximately 2 days (Courtney et al. 2017, Sikora-klak et al. 2017), while some studies still report averages greater than 5 days (Lo et al. 2017, Roger et al. 2019). Cultural factors may also be involved, as one Italian study reported an average LOS of 15 days for TKA patients operated on in 2011 to 2012 (Maiorano et al. 2017).

The introduction of fast track protocols, including early mobilization and multimodal pain management, has enabled a substantial reduction of LOS (Pamilo et al. 2018). Shorter LOS reduces the costs associated with TJA (Molloy et al. 2017), and also seems to reduce the risk of readmission without increasing complication rates (Williams et al. 2017). Furthermore, a shorter LOS is also associated with increased patient satisfaction (Tsai et al. 2015).

TJA routines and LOS have changed substantially in recent decades. Therefore, in many cases only the most recent studies are of interest when comparing results and identifying means to further reduce LOS.

Table 1. Risk factors for prolonged LOS following primary TJA from studies published during the last 5 years.

Author	Year	Journal	Country	N, TKA/THA	Risk factors identified	Mean LOS TKA	Mean LOS THA
Bradley et al.	2014	J Arthroplasty	UK	254/252	higher age, higher BMI, longer duration of surgery	4.1	4.3
Bohl et al.	2016	J Arthroplasty	US	29628/19975	hypoalbuminaemia	3.1	
Boylan et al.	2017	J Arthroplasty	US	115053/-	surgery later in the week	3.3	-
Courtney et al.	2017	J Arthroplasty	US	2870/1298	higher age, female gender, BMI >35, lower SES	2.3	2.3
Debbi et al.	2019	J Arthroplasty	US	-/63446	smoking	-	2.6
Farley et al.	2019	J Arthroplasty	US	-/1278	higher age, black race, single marital status, higher CCI, higher opioid consumption postoperatively, postoperative anaemia, high glucose levels	-	1.89
Featherall et al.	2018	J Arthroplasty	US	-/6090	higher age, female gender, higher BMI, black race, low hospital volume, low surgeon volume, higher CCI, public insurance	-	3.21 -> 2.55[a]
Halawi et al.	2015	J Arthroplasty	US	260/-	higher number of comorbidities, lack of assistance at home, bilateral TKA	3.0	-
Harthog et al.	2015	Bone Joint J	The Netherlands	-/477	higher age, living alone, lateral surgical approach	-	2.9
Husted et al.	2016	Acta Orthop	Denmark	6536/7194	BMI >35 (only in THA patients)	2*	2*
Ifeoma et al.	2015	J Arthroplasty	US	2638/2445	higher age, female gender, ASA Score >2, lower SES, non-Caucasian ethnicity, certain comorbidities, longer duration of surgery	-	3.5
Ihekweazu et al.	2018	World J Orthop	US	806/-	higher age, female gender, bilateral TKA, allergies, later procedure end times, being black or African American, not being married	2.0*	-
Lo et al.	2017	Hong Kong Med J	Hong Kong	1622/-	higher ASA score, bilateral TKA, in-patient complications, need for blood transfusion, postoperative ICU admission, urinary catheterization	6.8	-

Maiorano et al.	2017	Knee	Italy	353/-	higher age, lower Modified Berthel Index score	14.9	-
Mathijssen et al.	2016	Knee Surg Sports Traumatol Arthrosc	The Netherlands	879/-	higher age, female gender, higher ASA score, living alone, neurological comorbidities, general anaesthesia, surgery later in the week	2.9	-
Murphy et al.	2018	Bone Joint J	Australia	2838/-	higher age	4.0*	
Murphy et al.	2018	J Arthroplasty	Australia	-/2457	higher age	-	5.3
Patterson et al.	2018	J Arthroplasty	US	214005/129370	dialysis dependence	3.1	2.9
Pugely et al.	2014	Clin Orthop Relat Res	US	516745/-	higher age, multiple comorbidities, Hispanic ethnicity, black race, discharge to further care	-	-
Rhee et al.	2018	Can J Surg	Canada	17243/10123	higher age, female gender, multiple comorbidities, blood transfusion	5.1	5.7
Roger et al.	2019	Orthop Traumatol Surg Res	France	725/938	higher age, female gender, diabetes, surgery on Friday	5*	5*
Sibia et al.	2016	J Arthroplasty	US	-/273	higher age, female gender, ASA Score >2, higher BMI, coronary artery disease, general anaesthesia, longer operative time, increased blood loss, posterolateral approach, not ambulating on day of surgery	-	2.0
Sikora-Klak et al.	2017	J Arthroplasty	US	2009/905	higher age, female gender	2.4	2.4
Winemaker et al.	2015	Can J Surg	Canada	900/559	higher age, female gender, ASA Score >2, THA vs TKA, cardiovascular comorbidities	4*	4*
Zhang et al.	2018	J Orthop Surg Res	China	241/-	valgus deformity, increased IL-6 levels, increased VAS pain and CRP postoperatively, postoperative wound complications	3.8	-

* median

[a] The study evaluated the introduction of a care pathway protocol; LOS was lowered from 3.21 to 2.55 after implementing the protocol.

ASA, American Society of Anaesthesiologists; CCI, Charlson Comorbidity Index; SES, Socioeconomical status; CRP, C-reactive protein; VAS, Visual Analogue Scale. *Adapted and reprinted with permission. Saku et al. Reasons and Risk Factors for Delayed Discharge After Total Knee Arthroplasty Using an Opioid-Sparing Discharge Protocol. J Arthroplasty. 2019;34(10):2365-70. Copyright Elsevier (2019).*

2.4.1 Reasons for delayed discharge

A prospective Danish study with a median LOS of 2 days investigated the reasons for delayed discharge after TJA (Husted et al. 2011). The authors evaluated the fulfilment of the strict functional discharge criteria twice a day and recorded any specific underlying reason for not being able to be discharged. The results indicated that pain, dizziness, and muscle weakness were the most common reasons for delayed discharge. Confusion and nausea only played a minor role. In about 20% of the cases, a logistical reason (for example waiting for physiotherapy or postoperative x-rays) delayed the discharge.

In a UK study by Napier et al. (2013), 75% of the patients were discharged within 3 days after surgery and the authors documented any reasons for discharge after this time. In the THA population, social reasons accounted for half of the delayed discharges. Among TKA patients, social reasons delayed one third of the discharges, and mobilisation-related issues delayed one fifth. Other reasons that led to delayed discharge were low haemoglobin, respiratory problems, and anticoagulation-related issues. Akin to the study by Husted and colleagues (2011), nausea and confusion were of minor importance.

Although there are many studies that investigated risk factors for delayed discharge, very few studies report specific reasons for the delayed discharge.

2.4.2 Risk factors for delayed discharge

Table 1 lists risk factors identified in studies published during the last 5 years. Many risk factors are non-modifiable and hence provide a basis for risk-stratification rather than a means for intervention. However, some risk factors are modifiable and may prove helpful in reducing the LOS.

2.4.2.1 Non-modifiable patient-specific risk factors

Most studies report that higher age and female gender are important risk factors for delayed discharge (**Table 1**). While these are of course non-modifiable, they nevertheless help to identify which patients have the highest risk for delayed discharge and need the most attention to ensure timely discharge. It is unclear why female patients stay longer in hospital, but this may be attributable to social and psychological reasons.

The American Society of Anaesthesiologists (ASA) score is a scoring system for general health and comorbidity burden and was originally designed to evaluate the surgical risk (Keats 1978). According to several studies, ASA class 3 to 4 patients have an increased risk for prolonged LOS (Inneh 2015, Mathijssen et al. 2016, Sibia et al. 2016). Similarly, a higher Charlson Comorbidity Index (CCI) also increases the risk of delayed discharge (Featherall et al. 2018). The CCI quantifies the total burden of several comorbidities, including history of myocardial infarction, diabetes, cancer, and pulmonary disease (Charlson et al. 1987). Several individual comorbidities, especially diabetes mellitus and coronary artery disease, also increase the risk for longer LOS (Winemaker et al. 2015, Sibia et al. 2016, Roger et al. 2019).

As is evident from the reasons for delayed discharge, social reasons play a major role. Not being married, living alone, black race, and low socioeconomical status are independent risk factors for delayed discharge (Mathijssen et al. 2016, Courtney et al. 2017, Ihekweazu et al. 2018, Farley et al. 2019).

The modern fast track protocol uses strictly functional discharge criteria, and the preoperative level of fitness is therefore relevant for timely discharge. Preoperative use of walking aids is a known risk factor for longer LOS (Husted et al. 2008, Ong and Pua 2013). The benefit of preoperative rehabilitation, or “prehabilitation”, however, seems to be only small to moderate (Moyer et al. 2017). Not ambulating on the day of surgery predicts later discharge (Sibia et al. 2016) and could serve as a warning signal when monitoring rehabilitation progress.

2.4.2.2 Modifiable patient-specific risk factors

Although some patient-specific risk factors may be modifiable, it is unclear whether modifying these risk factors translates directly into shorter LOS. Hypoalbuminaemia, which partly reflects poor nutritional status, increased the risk of prolonged LOS in a large US study (Bohl et al. 2016) and should be corrected prior to surgery if possible. Smoking was associated with an increase in LOS from 2.5 to 3.0 days in a study on THA patients (Debbi et al. 2019) and should definitely be discouraged prior to even planning surgery. Smoking also increases the risk of cardiovascular complications and infections after TJA, among other complications (Truntzer et al. 2017). An 8-week smoking cessation program effectively reduced the risk of these complications (Truntzer et al. 2017).

There is conflicting evidence regarding what impact obesity has on LOS. For moderately obese patients, no convincing evidence exists that obesity increases the risk of delayed discharge. However, several studies suggest that the risk of prolonged LOS is higher for very obese and morbidly obese patients (BMI >35), especially THA patients (Husted et al. 2016, Courtney et al. 2017, Featherall et al. 2018). It is unclear how and when these patients should be encouraged to lose weight to reduce the risk of complications.

2.4.2.3 Hospital-specific risk factors

Some studies suggest that GA leads to longer LOS compared with spinal anaesthesia (Mathijssen et al. 2016, Sibia et al. 2016). A meta-analysis of randomized controlled trials and prospective comparative studies (total 10 000 patients) revealed that LOS was almost half a day shorter for patients receiving neuraxial anaesthesia compared to GA (Johnson et al. 2016). On the other hand, a large retrospective study utilizing propensity-adjusted multivariate analyses of 21 000 THA patients revealed that although GA was generally associated with poorer outcomes, it was not associated with prolonged LOS compared with spinal anaesthesia (Basques et al. 2015). Hopefully, an ongoing Finnish randomized controlled trial comparing general and spinal anaesthesia will provide more conclusive evidence on the impact of anaesthesia type on LOS (Rantasalo et al. 2018).

The length of surgery is inversely correlated with LOS (Bradley et al. 2014, Sibia et al. 2016). Undergoing surgery towards the end of the week also increases LOS (Mathijssen et al. 2016, Boylan et al. 2017, Roger et al. 2019) and likely reflects the reduced availability of physiotherapy and fewer staff during the weekends. In accordance with the trend of increasing centralization efforts, both lower hospital and lower surgeon volume are linked to increased LOS (Pamilo et al. 2013, 2015, Featherall et al. 2018).

One study suggests that postoperative anaemia increases the risk for prolonged LOS (Farley et al. 2019). Increased blood loss and the need for postoperative blood transfusions have also been linked to longer LOS (Sibia et al. 2016, Lo et al. 2017), which highlights the importance of good haemostasis during surgery and evidence-based transfusion guidelines.

2.4.2.4 Other risk factors

There are only a few risk factors that emerge during the postoperative period. One of these is the amount of opioids consumed during the first postoperative days. The more opioids the patient requires, the higher the likelihood of staying longer (Farley et al. 2019).

2.4.3 Reducing LOS

In a large analysis by Grosso and colleagues (2019) that included over 600 different hospitals across the US, LOS decreased steadily from 3.8 days in 2006 to 2.7 days in 2016, with a subsequent decrease in all complications measured. The 30-day readmission rates also did not change.

A nation-wide Danish study (Husted et al. 2010) assessed hospital factors associated with shorter LOS. The authors found that hospitals with shorter LOS had lower staff turnover, functional discharge criteria that were evaluated several times a day, multimodal opioid-sparing analgesia, and early mobilization. The study also revealed that patients treated at hospitals with shorter LOS were just as satisfied, or more satisfied, than patients treated at hospitals with longer LOS. The staff resources were similar across all hospitals. This study was published almost 10 years ago, and many of these elements are currently commonplace in most large academic arthroplasty centres.

Single-institution studies have shown that implementing a fast track protocol effectively reduces LOS without compromising quality of care. A recent study (Stone et al. 2018) analysed the effects of implementing an Enhanced Recovery After Surgery (ERAS) protocol. Amongst other things, the ERAS introduced ambulation on the day of surgery and discontinued patient-controlled analgesia in favour of multimodal pain management. LOS decreased from 2.66 to 1.63 days during the 5-year study period and neither emergency department (ED) visits nor readmission rates increased.

Bernstein and colleagues (2018) evaluated the implementation of a preoperative optimization protocol, which helped to optimize modifiable patient-specific risk factors prior to surgery. This included several laboratory tests and a screening protocol for, amongst others, tobacco, alcohol, and narcotics use, depression and anxiety disorders, obstructive sleep apnoea, lower extremity wounds, cardiac diseases, and high BMI. Patients received optimization interventions if they met "yellow flag" or "red flag" criteria for these risk factors. Three fourths of the post-implementation study patients had at least one risk factor. As a result of implementing the screening protocol with subsequent optimization measures, LOS was reduced from 2.2 to 1.9 days, direct costs were reduced from $5852 to $5409, and the 90-day readmission rate stayed the same.

As low hospital and surgeon volume are risk factors for longer LOS, it is likely beneficial to centralize arthroplasty surgery to large tertiary centres, thereby enabling better routines and a more streamlined fast track protocol (Pamilo et al. 2013).

Preoperative education and particularly physiotherapy also seem to reduce LOS. However, the effects are only small to moderate and the evidence is somewhat inconsistent (Moyer et al. 2017).

Psychology plays a significant role in reducing LOS. Managing patient expectations is therefore important. In a study by Tanzer and colleagues (2018), the treating surgeon told the patients on the preoperative visit to expect either a 2-day or 4-day LOS. All patients received a brochure that clearly stated the expected discharge date. Despite treating all patients according to the same 4-day LOS protocol, the difference was substantial. The LOS in the group that expected a 2-day LOS was on average a whole day shorter compared to the group that expected a 4-day LOS.

In the future, the application of various technological solutions (such as telemedicine) will likely increase. This provides new ways to reduce LOS even further, for example by providing support and careful follow up of the patients at home instead of having them stay an extra day at the hospital (Vesterby et al. 2017).

2.4.4 Financial implications of LOS

In addition to improvements in clinical outcomes and patient satisfaction, reducing LOS is a highly efficient way to reduce the costs associated with TJA. For example, by implementing a THA care pathway and reducing the LOS from 3.21 to 2.55 days, the direct and post-discharge costs were reduced by an estimated $2500 per patient (Featherall et al. 2018). The number of discharges to home increased, without any change in 90-day readmissions, as in most other similar studies.

Another study used a Medicare sample to compare the total costs at 2 years after TJA among groups with different LOS (Lovald et al. 2014). Compared to a "standard group" with a 3- to 4-day LOS, the results revealed that the costs were $1200 higher in the >5-day group, $2000 lower in the 1- to 2-day group, and $8500 lower in the outpatient group. The groups with shorter LOS experienced less pain and stiffness but had, however, a slightly higher risk for readmission, revision, and mortality than the 3- to 4-day group. This is in contrast with most other studies that suggest that shorter LOS does not increase the complication rates. The cost savings were, however, substantial.

In a Canadian study on TKA patients (Huang et al. 2017), the costs decreased by 30% when discharging selected patients on the day of surgery. The control group was treated using a normal fast track protocol and had an average LOS of 2.8 days. In this study, the cost reduction was mostly related to lower ward and nursing costs and lower pharmacy and meal costs.

2.4.5 Outpatient TJA

The ultimate goal of reducing LOS is outpatient TJA. This has gained considerable popularity recently, and performing THA and TKA with same-day discharge seems to be safe in selected patients (Pollock et al. 2016). Several risk assessment tools have appeared to facilitate patient selection, for example the Outpatient Arthroplasty Risk Assessment (OARA) score (Meneghini et al. 2017). The OARA risk score assesses nine comorbidity areas and has a high predictive value for same- or next-day discharge.

In unselected patients, outpatient TJA seems to be feasible in about 15% of the patients (Gromov et al. 2017). Further studies are still required to provide more rigorous evidence on patient selection and the safety and effectiveness of outpatient TJA (Pollock et al. 2016).

2.5 PATIENT CONCERNS AFTER DISCHARGE

Reducing post-discharge patient concerns begins well in advance before the surgery. Patients receive education in all parts of the pre-surgery process, including the clinical examinations, physiotherapy and nurse visits, and patient education classes. They often also receive written material. Important aspects include goal-setting for when to leave the hospital and managing expectations for postoperative pain and function levels.

2.5.1 Patient education

A large systematic review of preoperative exercise and education showed small to moderate improvements in postoperative pain (only THA patients) and function together with a decrease in LOS (Moyer et al. 2017). A qualitative interview study revealed that TJA patients needed more information regarding expected pain levels and the use of painkillers (Kennedy et al. 2017). They especially wanted better information on how and when to reduce the medication to avoid addiction.

In an analysis of the Swedish Hip Arthroplasty Registry (Torisho et al. 2019), the authors observed that patient education and physiotherapy prior to surgery had a minor influence on postoperative patient-reported outcome measures (PROMs). However, the effect was too small to draw any definite conclusions.

A Cochrane review drew similar conclusions, namely that it is unclear whether preoperative education offers benefits with regard to pain, anxiety, function, and surgical outcomes when compared with usual care (McDonald et al. 2014). The authors recommend that because of the low risk of undesirable effects, preoperative education may still be useful, especially in certain patient groups such as those with depression, anxiety, and unrealistic expectations. A Danish systematic review also found no convincing evidence in favour of preoperative education (Aydin et al. 2015).

2.5.1 Emergency department visits

Unnecessary ED visits add to the healthcare burden and increase the costs associated with TJA (Sibia et al. 2017). There is a large number of potentially unnecessary ED visits after TJA that could be better managed in other ways (Rossman et al. 2015, Chaudhary et al. 2018).

Patients visiting the ED after TJA usually complain about pain and swelling, and up to 90% of the patients leave the ED without being admitted to the hospital (Rossman et al. 2015, Sibia et al. 2017, Stone et al. 2018). A large study including more than 150 000 patients revealed that the ED visit rate within 30 days of TJA was nearly double that of the readmission rate (5.8% vs 3.4%) (Finnegan et al. 2017). In a UK study with 2350 TJA patients, 15% of the patients visited the ED within 90 days of discharge (Tucker et al. 2018). This was also double the amount of readmissions at 90 days (6.8%). Furthermore, in a US study by Kelly and colleagues (2018), the 90-day ED visit rate (14%) was nearly three times as high as the readmission rate (5%). There are considerably fewer studies on ED visits than on readmissions. Considering these data, it seems that ED visits pose a larger healthcare burden than what is generally acknowledged. ED visits may also be easier to prevent than readmissions.

In the study by Finnegan and colleagues (2017), the ED utilization rates differed substantially between different ethnic and payer groups. Patients with Medicaid and Medicare insurance had a significantly higher risk for ED visits than those with private insurance. Black race was also an independent risk factor for ED visits. Pain seems to be a common issue after TJA, as one fourth of all patients received a pain-related diagnosis upon visiting the ED. Oedema and infection were also common diagnoses.

2.5.2 Phone consultation services

One way to reduce patient concerns after surgery is to improve outpatient communication, for example via a phone consultation service. This kind of service may reduce the amount of ED visits by enabling patients to solve some of their concerns by phone. A phone service that is open during non-office hours could help reduce unnecessary ED visits (Kee et al. 2019). In the study by Kee and colleagues (2019), most calls were resolved by simple reassurance over the phone. Pain and swelling constituted the most common concerns, similar to the ED visits previously mentioned. Only 12% of the patients in the study by Kee and colleagues received instructions to visit the ED. Of these patients, roughly half needed treatment. Only four patients (7.5%) visited the ED despite not being instructed to, and none of these received any medical intervention.

A phone consultation system that works the other way around (i.e. patients are called on a scheduled basis after TJA) is also beneficial. This kind of system reduced the amount of readmissions for healthier patients, but not for patients with high ASA scores (Edwards et al. 2017).

Tucker and colleagues (2018) investigated which effect a slightly different phone consultation system had on ED visit rates. Patients received three different instructions on how to handle postoperative concerns. The first group received instructions to simply contact their general practitioner (GP) should any concerns arise. The other group received instructions to call a helpline phone number and the third group received both instructions to call the helpline phone number and also received a phone call on postoperative day 5 to remind them of the helpline phone. The rate of unscheduled GP attendance or ED visits was 30% in the group without helpline access. This was reduced to 26% in the group with helpline access, and further reduced to 22% in the group with both helpline access and a phone call on day 5 reminding them about the helpline. Running this helpline service system also provided some cost savings.

2.6 READMISSIONS

A readmission is usually defined as any hospitalization to any hospital occurring within a certain time window after discharge from the index procedure. However, the literature varies considerably with regards to which readmissions are included in the readmission rates. Large nationwide studies generally use all-cause readmissions and include every hospitalization within a certain region (Kurtz et al. 2016a). This is likely related to the difficulty to extract more detailed data on each specific readmission.

In smaller studies including just a few hospitals, it is possible to obtain more detailed data on the reasons for readmissions, and hence unplanned readmissions (i.e. those that were not planned at discharge) are usually reported (Saucedo et al. 2014, Ricciardi et al. 2017). Some authors decided to include only those unplanned readmissions that are possibly associated with the index procedure (Paxton et al. 2015); hence appendicitis, cancer surgeries, and similar readmission reasons are excluded. While this is not as objective as counting all readmissions, the unplanned (and index surgery related) readmissions are indeed the ones of most relevance.

A study comparing three different readmission rates (all-cause, readmission for surgical diagnoses, and return to theatre [RTT] readmissions) revealed that readmission rates for surgical diagnoses varied most between both surgeons and hospitals (Bottle et al. 2018). All-cause readmission rates varied the least. It can therefore be argued that surgical readmissions are the best ones to consider when analysing and comparing performance and quality of care. However, this is not possible in all study settings.

The most commonly used time periods for readmissions are 30 and 90 days after discharge (Ali et al. 2017, Tucker et al. 2018). In some studies, the time period is calculated from the day of surgery instead of the day of discharge (Mednick et al. 2014), although this does not significantly change the readmission rates (Chen et al. 2017). Compared to a 30-day time period, Chen and colleagues (2017) also found that a 90-day time period is superior with regards to capturing relevant surgical readmissions.

The various definitions of readmissions make it somewhat difficult to compare readmission rates among different studies, and one must be very careful when determining exactly which readmissions were counted in a specific study. Moreover, some single-institution studies might miss a part of the readmissions as some patients are readmitted to other hospitals (Phillips et al. 2019).

2.6.1 Readmission rates after TKA

The reported readmission rates after TKA vary between 0.2% to 6.6% at 30 days and 3.3% to 8.6% at 90 days after primary discharge (Raines et al. 2015, Kurtz et al. 2016b, Ricciardi et al. 2017). Most of the studies report rates between 4% and 8%. **Table 2** shows readmission rates from the most recent studies. In the largest single study performed by Kurtz and colleagues (2016b), including nearly a million patients treated at more than 3800 different hospitals across the US, the median all-cause readmission rate was 4.9% at 30 days and 8.6% at 90 days after discharge. Interestingly, the readmission rates for the individual hospitals included in this study varied from 0% to 22% at 30 days and 0% to 32% at 90 days.

2.6.2 Readmission rates after THA

The readmission rates after THA are often similar to readmission rates after TKA. There are studies reporting both higher (Raines et al. 2015, Kurtz et al. 2016a), lower (Saucedo et al. 2014, Tucker et al. 2018), and similar rates (Husted et al. 2016) for THA compared with TKA. THA readmission rates vary from 0.3% to 8.4% at 30 days and 4.5% to 10.5% at 90 days (**Table 2**). Akin to TKAs, there is also a wide variation in readmission rates after THA surgery between hospitals within the same country (2016a).

Table 2. 30- and 90-day readmission rates after TJA from studies published in the last 5 years.

Author	Year	Journal	Country	N (TKA/THA)	TKA		THA		Readmissions counted
					30-day	90-day	30-day	90-day	
Ali et al.	2019	J Arthroplasty	UK	566323 / -	6.0%	-	-	-	Unplanned[1]
Ali et al.	2019	JAMA Surg	UK	- / 514455	-	-	5.9%	-	Unplanned[2]
Apuzzo et al.	2017	J Bone Joint Surg Am	US	337705 / -	5.8%	-	-	-	All-cause
Bottle et al.	2018	J Arthroplasty	UK	311033 / 25980	5.8%	-	5.5%	-	All-cause[3]
Gold et al.	2016	J Arthroplasty	US	132422 / 65071	-	7.9%	-	8.3%	All-cause
Husted et al.	2016	Acta Orthop	Denmark	6536 / 7194	5.9%	8.3%	6.1%	8.6%	N/A
Keeney et al.	2015	J Arthroplasty	US	3372 / 4131	3.8%	-	4.1%	-	N/A
Kelly et al.	2018	J Arthroplasty	US	5520 / 2344	-	5.5%	-	4.5%	All-cause
Kurtz et al.	2016	J Arthroplasty	US	952593 / 442333	4.9%	8.6%	5.8%	10.5%	All-cause
Lee et al.	2017	The Knee	Korea	4596 / -	1.9%	3.3%	-	-	Unplanned
Paxton et al.	2015	Clin Orthop Relat Res	US	- / 12030	-	-	3.6%	-	Related to index surgery
Raines et al.	2015	J Arthroplasty	US	16808 / 9902	6.6%	-	8.4%	-	N/A
Ricciardi et al.	2016	J Arthroplasty	US	10759 / 11105	0.2%	-	0.3%	-	Unplanned
Saucedo et al.	2014	J Arthroplasty	US	3890 / 2524	4.7%	8.2%	3.4%	7.2%	Unplanned
Tucker et al.	2018	J Arthroplasty	UK	1010 / 1341	4.7%	7.9%	3.8%	5.9%	N/A
Urish et al.	2018	J Arthroplasty	US	4465 / -	4.0%	-	-	-	All-cause

[1]Readmissions with surgical diagnoses were 3.3%; return to theatre readmissions were 0.5%.
[2]Readmissions with surgical diagnoses were 3.25%; return to theatre readmissions were 0.8%.
[3]Readmission rates for surgical diagnoses were 3.1% for TKA and 2.9% for THA. Return to theatre readmissions were 0.5% for TKA and 0.8% for THA.
N/A, Information not available.

2.6.3 Reasons for readmission after TKA and THA

Apart from a few exceptions, the reasons for readmission are similar for TKA and THA. Some authors therefore choose to report them together (Saucedo et al. 2014). The readmission reasons are usually categorized as either surgical or medical. The surgical reasons are mainly those related directly to the index procedure, such as infection, periprosthetic fracture, dislocation, implant loosening, haematoma, thromboembolic disease, and wound problems (Kelly et al. 2018, Ali et al. 2019). The Knee Society has published its own standardized list of common surgical complications after TKA, including clear definitions and International Classification of Diseases 9th version (ICD-9) codes (Healy et al. 2013). However, this list is not always used.

Medical reasons include both medical conditions that can be associated with the index procedure, such as pneumonia, myocardial infarction, peptic ulcer, and urinary tract infection, as well as reasons that are totally unrelated to the procedure (Kelly et al. 2018). Surgical reasons are more common than medical reasons and account for more than half of the readmissions (Saucedo et al. 2014, Ali et al. 2019). Complications related directly to the surgical site are the most common among surgical complications (Ali et al. 2019).

Table 3 lists the most common reasons for readmission. Most studies conclude that infection-related readmissions are the most common after primary elective TJA (Saucedo et al. 2014, Ali et al. 2019). Even if the infections are categorized into superficial wound infection and prosthetic joint infection (PJI), both usually make it to the top of the list (Kelly et al. 2018). Gastrointestinal issues and cardiovascular complications (e.g. atrial fibrillation and myocardial infarction) are among the most common medical reasons for readmission (Kurtz et al. 2016a, Kelly et al. 2018).

There are some differences between the reasons for TKA and THA readmission. The number of periprosthetic fractures is much higher in THA patients (Kurtz et al. 2016a, 2016b), likely due to the more violent preparation of the femur, especially when using uncemented stems. Dislocation is also a common reason for readmission after THA (Kurtz et al. 2016b); dislocation is not a problem after TKA. Pain seems to be a more common reason for readmission for TKA patients than THA patients (Ricciardi et al. 2017).

One study reported manipulation under anaesthesia (MUA) as one of the most common reasons for readmission after TKA (Kelly et al. 2018). However, most studies did not report MUA as a common reason. It is also unclear whether MUA is counted as a readmission at all, whether it is classified as planned or unplanned, or just excluded for some other reason.

Table 3. Common reasons for readmission after TJA.

TKA	
Superficial wound infection or cellulitis	(Saucedo et al. 2014, Kurtz et al. 2016b, Ali et al. 2019)
Prosthetic joint infection	(Kurtz et al. 2016b, Kelly et al. 2018, Ali et al. 2019)
Pain	(Ricciardi et al. 2017)
Thromboembolic disease	(Kurtz et al. 2016b, Ali et al. 2019)
Gastrointestinal issues	(Kelly et al. 2018)
THA	
Prosthetic joint infection	(Paxton et al. 2015, Kurtz et al. 2016a, Kelly et al. 2018)
Dislocation	(Saucedo et al. 2014, Paxton et al. 2015, Kurtz et al. 2016a, Ricciardi et al. 2017)
Periprosthetic fracture	(Saucedo et al. 2014, Kurtz et al. 2016a)
Thromboembolic disease	(Ali et al. 2017)
Superficial wound infection or cellulitis	(Kurtz et al. 2016a, Ali et al. 2017)

2.6.4 Risk factors for readmission

Risk factors for readmission after TJA include both patient-, hospital- and payer-specific factors. The most established risk factors are listed in **Table 4.**

2.6.4.1 Patient-specific risk factors

Many patient-specific risk factors are unfortunately non-modifiable. Knowing these risk factors is still important in both risk stratification of patients (Goltz et al. 2019) and when creating value-based payment models, such as the Comprehensive Care for Joint Replacement Payment Model that the Centers for Medicare and Medicaid Services in the US recently initiated (Williams et al. 2017).

Table 4. Key risk factors for readmission after TJA.

Patient-specific	
Age >80 years	(Paxton et al. 2015, D’Apuzzo et al. 2017, Lee et al. 2017, Tucker et al. 2018, Urish et al. 2018, Ali et al. 2019)
BMI <20 or >35	(Saucedo et al. 2014, Keeney et al. 2015, Paxton et al. 2015)
Coronary artery disease	(Saucedo et al. 2014, Keeney et al. 2015)
Depression	(Gold et al. 2016, Ricciardi et al. 2017)
Diabetes mellitus	(Saucedo et al. 2014, Keeney et al. 2015, Urish et al. 2018)
ED visits prior to surgery	(Ali et al. 2017)
Lower socioeconomical status	(Ali et al. 2017)
Male gender	(Paxton et al. 2015, D’Apuzzo et al. 2017, Williams et al. 2017, Urish et al. 2018)
TKA (vs THA)	(Williams et al. 2017)
Hospital- and procedure-specific	
Discharge disposition other than home	(Keeney et al. 2015, Kurtz et al. 2016a, D’Apuzzo et al. 2017, Ricciardi et al. 2017)
Increased tourniquet time (TKA)	(Ricciardi et al. 2017)
Lower hospital volume	(Pamilo et al. 2013, Kurtz et al. 2016a)
Lower surgeon volume	(Kurtz et al. 2016a)
Non-profit hospital ownership	(Kurtz et al. 2016a)
Other risk factors	
Longer LOS	(Keeney et al. 2015, D’Apuzzo et al. 2017, Williams et al. 2017, Urish et al. 2018)
Medicare or Medicaid insurance	(Saucedo et al. 2014, Keeney et al. 2015, D’Apuzzo et al. 2017)

Higher age is by far the most commonly reported risk factor, with risks increasing significantly around the age of 75 to 80 years (Ali et al. 2017, Tucker et al. 2018). Some studies also report a U-shaped association between age and readmissions, with patients younger than 50 years having a slightly increased risk (Ali et al. 2019). This may reflect the heterogeneity of TJA indications in this younger population, possibly including more complex cases and hence more complications.

In studies that investigate the effect of certain comorbidities, often those included in the CCI (Charlson et al. 1987), several different comorbidities usually emerge as risk factors (Keeney et al. 2015, Paxton et al. 2015). Some of the most important diseases are diabetes mellitus, coronary artery disease, and depression (Keeney et al. 2015, Gold et al. 2016, Urish et al. 2018). Other risk factors include male gender and low socioeconomical status (SES) (Ali et al. 2017, D'Apuzzo et al. 2017). Higher readmission rates are reported both for TKA and THA depending on how and where the study was performed, but one study that directly compared TKA with THA patients revealed that TKA is an independent risk factor for readmission compared to THA (Williams et al. 2017).

Of the modifiable patient-specific risk factors, BMI is of particular interest. Both a BMI too low and a BMI too high seem to increase the risk of readmission (Saucedo et al. 2014, Paxton et al. 2015). However, it is unclear whether losing weight prior to a TJA surgery is beneficial with regards to the risk of readmission.

2.6.4.2 Hospital-specific risk factors

Several studies have demonstrated that lower hospital volume is associated with a higher risk of readmission (Pamilo et al. 2013, Kurtz et al. 2016a). In Finland, the tendency is to centralize arthroplasty surgery to ever fewer specialized high-volume centres. This seems to be beneficial with regards to readmissions and other outcomes. The surgeon volume is also inversely associated with readmission risk (Kurtz et al. 2016a); it therefore seems beneficial to share the TJAs among as few surgeons as possible, at least in the lower-volume hospitals.

Most studies conclude that discharge directly to home should be the primary target to reduce readmissions, although this is of course not possible for all patients (Kurtz et al. 2016a, D'Apuzzo et al. 2017). Most discharge dispositions other than home are associated with an increased risk of readmission.

2.6.4.3 Other risk factors

A longer LOS increases the readmission risk in almost all studies (D'Apuzzo et al. 2017, Williams et al. 2017). Longer LOS also increases the risk for several other complications, as described in the LOS section.

Medicare patients seem to have slightly higher readmission rates than non-Medicare patients (Urish et al. 2018). If the patient was discharged to further care in a skilled nursing facility, the Medicare population had much higher readmission rates (48% vs 25%). Although this is of importance in the US, in healthcare systems where everyone is insured by the government (for example in the Nordics), the results from these US studies may not be directly applicable. Hence more studies are needed in our type of healthcare system.

Lower patient satisfaction is also linked to a higher risk for readmission (Sodhi and Mont 2019).

2.6.4.4 Using the risk factors in practice

Recently, risk calculators that are sufficiently predictive to be incorporated into daily clinical practice have appeared (Goltz et al. 2019). These risk calculators enable the staff to easily identify high-risk patients even before they enter the hospital. This way, the medical staff can undertake preventive measures and accordingly adjust resource allocation, thus offering more support to higher-risk patients. The risk calculators can also be used in patient education and when developing larger-scale reimbursement models.

2.6.5 Financial implications of readmissions

According to a recent US study (Phillips et al. 2019), the cost for readmission episodes within 90 days of discharge in a bundled payment system averaged $8588. Readmissions for revision surgery were the most expensive, with a mean cost of $15 356. In the same study, the authors also noted that 50% of the patients were readmitted to another hospital than where they had undergone the index surgery.

Considering that the 90-day readmission rate is approximately 8% on average, readmissions account for a very high cost. Many of the risk factors are *de facto* non-modifiable, but even for these risk factors, identifying the patients at most risk may help reduce the total risk by providing extra support to high-risk patients already before surgery.

Telemonitoring and similar future technological solutions may provide better and more cost-effective ways to follow TJA patients in the early post-discharge period. This could encourage rehabilitation and help resolve any concerns before they result in a readmission (Rosner et al. 2018). According to one study, only a small percentage of readmissions are actually preventable (Weinberg et al. 2017); further studies are needed to determine if these results are generalizable. By reducing other deviations in TJA (e.g. reducing the amount of patients with delayed discharge), the amount of readmissions will also likely decrease, as these factors are linked.

2.7 QUALITY METRICS

There is much controversy regarding the quality measurement of TJA. Recent efforts in the US have focused mainly on reducing readmissions, but other quality metrics are also important.

2.7.1 LOS

LOS is an easily accessible variable that is objective and is recorded in almost any kind of hospital registry. As LOS is more objective than certain coded complications (subject to bias due to non-standard coding and reporting errors), LOS could be a good surrogate marker for quality of care. Patients that experience complications during or early after surgery are likely to spend extra days in hospital. In other surgical specialities, for example heart and colorectal surgery, LOS is a highly sensitive marker for complications (Fry et al. 2009).

However, prolonged hospitalization seems to correlate poorly with relevant complications in studies on elective arthroplasty (Lyman et al. 2015). It seems that LOS cannot be used as a direct quality metric. On the other hand, if the number of readmissions, infections, mortality, and similar complications are all on an acceptable level, then shorter LOS would indicate better-functioning fast track routines and likely higher quality of care. Since shorter LOS is linked to lower costs (Molloy et al. 2017), higher patient satisfaction (Tsai et al. 2015), and less complications (Williams et al. 2017), it is still a good objective for hospitals to reduce LOS regardless of whether it is used as a direct quality metric or not.

2.7.2 Readmissions and ED visits

A recent systematic review analysed the validity of using all-cause 30-day readmission rates (ACRR) as a hospital performance metric (Ali and Bottle 2019). The authors concluded that there is insufficient evidence to warrant the use of ACRR directly as such for comparing hospital performance, as the variability in ACRR was mostly related to patient factors and not hospital-level factors. The authors suggest that combining ACRR with mortality rate or using surgical readmission rates (instead of all-cause readmissions) would improve the sensitivity in detecting differences in quality of care.

A study comparing three different types of readmission rates (all-cause, surgical, and RTT) also indicated that surgical readmission rates better reflect both hospital- and surgeon-level differences than all-cause readmissions (Bottle et al. 2018). The problem with using surgical readmissions is the potential for coding bias, with readmission rates highly dependent on which surgical reasons are recorded.

Furthermore, only measuring readmissions when assessing quality of care may provide incomplete information. Although readmissions are associated with much higher costs, ED visits usually occur at least at twice the rate of readmissions (Trimba et al. 2016, Finnegan et al. 2017). Thus, measuring ED visits should also be of interest to the care provider.

2.7.3 Mortality

Mortality rate is an important quality metric. It is objective and reflects quality of care, patient selection, surgical approach, thromboprophylaxis, and management of major complications after surgery (Jørgensen et al. 2017). Several national arthroplasty registries include 90-day mortality rates, which vary between 0.2% to 0.8% (Jørgensen et al. 2017, Malchau et al. 2018).

2.7.4 Revision rate

Another important quality metric is the early revision rate (within 2 years after surgery) (The Finnish Arthroplasty Association 2015). It can easily be argued that a well performed TJA performed on adequately selected patients for the right indications should have a very low revision rate within the first few years after surgery. Revisions within the first 2 years after surgery are often related to either infection or surgical technique (such as periprosthetic fracture, aseptic loosening, and dislocation in THA, and stiffness or instability in TKA) (Singh et al. 2016) and thus reflect the quality of care well. The rate of early infections (e.g. revisions due to infection) is also an important quality metric that may be used alone or together with the all-cause revision rate.

Directly comparing revision rates between different hospitals can be somewhat difficult, as larger university hospitals usually take on more difficult cases, while smaller hospitals more often have the bulk of “normal” primary arthroplasties. To enable a fair comparison, patient characteristics should be considered. If, for example, only primary surgeries on ASA class I-II (i.e. healthy) patients that have BMI <35 with primary OA as the surgical indication are compared, the revision rates should not differ. If the revision rates for these “easy” and “normal” cases differ significantly, then there is most likely a difference in quality of care. One drawback with this type of comparison of adjusted revision rates is the high number of patients needed to lessen the risk for statistical variation; the smaller hospitals may not always have high enough annual volumes to enable a fair comparison.

2.7.5 Patient-reported outcome measures

Patient-reported outcome measures (PROMs) are among the most used and studied quality metrics in arthroplasty surgery in recent years. PROMs have been incorporated into several national arthroplasty registries, which provide a good basis for evaluating clinical improvement and patient satisfaction among different patient groups, implant types, and countries (Rolfson et al. 2016). Similar to PROMs, patient reported experience measures (PREMs) are also gaining attention as a quality metric (Kingsley and Patel 2017), with Net Promoter Score (NPS) (The Finnish Arthroplasty Association 2015) probably being the most common.

Several different PROMs are commonly used in TJA. The PROMs can be divided into general quality-of-life, condition-specific, and joint-specific questionnaires. Common questionnaires for general quality-of-life include SF-12, SF-36 (Short Form 12 and 36 health survey), and EQ-5D (EuroQol 5 Dimension). Common condition-specific PROMs include WOMAC (Western Ontario and McMaster Universities Arthritis Index), OKS (Oxford Knee Score), and OHS (Oxford Hip Score). Joint-specific PROMs include KOOS (Knee injury and Osteoarthritis Outcome Score) and HOOS (Hip disability and Osteoarthritis Outcome Score) (Rolfson et al. 2016).

For PROMs to be meaningful, a threshold for minimal clinically important difference (MCID) must be used instead of just evaluating statistical significance (corresponding perhaps to minimal, but clinically irrelevant changes) (Leopold and Porcher 2017). The MCID is usually defined as the minimal change that the patient can detect or that matters to the patient (Leopold and Porcher 2017). The use of MCID makes it easier to evaluate whether the result of an intervention really has a beneficial effect or just a statistically significant effect. A similar concept is the use of patient acceptable symptom state (PASS), which represents a threshold on a numerical scale above which the patient is considered well (Connelly et al. 2019). The PASS can hence be useful in cases where there is only one PROM value and no direct comparison.

To enable a feasible comparison of outcomes in different parts of the world, the International Society of Arthroplasty Registries recommends a minimum amount of PROMs and clinical variables that should be incorporated into arthroplasty registries worldwide (Rolfson et al. 2016). The Organisation for Economic Co-operation and Development (OECD) recommends using at least one generic and one condition-specific PROM. The recommended condition-specific PROMs are OHS for THA patients and OKS for TKA patients (OECD 2019). Current technology makes it easier than ever before to incorporate collection of PROMs into daily clinical practice (Ayers 2017).

3. AIMS OF THE STUDY

The aims of the present study were:

1. To assess the reasons for and outcomes of triggering the ERT at a high-volume arthroplasty centre and to assess the reasons for intensive care unit admission.

2. To investigate the risk factors and reasons for delayed discharge after TKA in a European healthcare setting, using an opioid-sparing protocol.

3. To evaluate the efficacy of a phone consultation service for TJA patients and to determine the rates and reasons for early post-discharge phone calls.

4. To assess the rates, reasons, and risk factors for 90-day readmission after TKA in a European healthcare setting.

4. PATIENTS AND METHODS

All patients underwent treatment at Peijas Hospital, the Helsinki University Central Hospital Arthroplasty Centre. Ethics Committee approval was not required due to the retrospective nature of this study. The Institutional Review Board approved the study protocol. The annual volume of TJA procedures during the study period were on average 1050 primary TKA, 140 revision TKA, 900 primary THA, and 220 revision THA.

4.1 IDENTIFICATION OF THE STUDY POPULATION

In **Study I**, TKA and THA patients were identified from prospectively collected ERT paper forms. The patient material consists of all ERT calls that occurred at the arthroplasty ward between 1 January 2014 and 31 December 2017. If one patient had several calls during the study period, these calls were treated as separate patients, except for the 30-day mortality analysis.

In **Studies II** and **IV**, the patients treated with primary elective TKA between 1 January 2015 and 31 December 2015 were identified by searching the institutional database with the NOMESCO procedure codes NGB20, NGB30, NGB40, and NGB50. All patients with a fracture or another non-elective indication surgery were excluded. Patients with bilateral surgery were excluded in **Study II**.

In **Study III**, the patients were identified by reviewing paper forms that had been prospectively completed for all patients calling the phone consultation service between 30 March and 31 May 2016. Calls made within 90 days of THA or TKA surgery were included in the study. Calls that occurred prior to surgery, were made by a patient's relative, or were not related to the TJA surgery were excluded.

Table 5. Demographics of **Studies II** and **IV**.

	Study II		Study IV	
	Case	**Control**	**Case**	**Control**
N	190	659	60	228
Age (years), mean	73.2	66.0	69.9	67.1
Gender, % female	75.8	65.6	60.0	64.5
BMI, kg/m2	29.5	29.8	29.9	29.6
Duration of surgery (min), mean	102	95.7	100	96.2

4.2 STUDY DESIGN

Study I was a retrospective cohort study consisting of 65 consecutive ERT activations in the arthroplasty unit during 4 years. During the ERT intervention, the nurse that made the ERT call completes a paper form. This form provided initial data on the date and time of call, which ERT criteria that triggered the call, which interventions were undertaken, and primary outcome. The patient medical records provided more detailed information on the ERT call and also revealed possible surgeries, ICU admissions, and deaths. The electronic medical records enabled tracking of the patients for 30 days after the ERT call. The 30-day mortality rate was confirmed by querying a national population registry in any unclear cases.

Study II was a retrospective case-control study with 849 patients that had undergone primary elective TKA. One hundred ninety patients had a LOS longer than the median of 3 days and were hence considered to have a delayed discharge. These patients were compared to the 659 patients with normal discharge using multivariable regression analysis to identify independent risk factors for delayed discharge. Medical records provided patient and surgical data and data from the preoperative physical examinations. The reason for delayed discharge was also assessed by reviewing the medical records.

Study III was a prospective study that assessed patient calls to a consultation phone service for TJA patients. The consultation phone service is operated by a nurse with experience in arthroplasty and is open every weekday from noon to 1 PM. The nurse who answered the phone completed a paper form that recorded the date, patient's name, the patient's main concern, and what was done to solve the concern (instructions given by phone, consulting a pain management nurse, consulting the attending surgeon, or directing the patient to the ED).

The electronic medical records provided more data about the patients and their preceding surgeries. All study patients were followed for 2 weeks after the call to track any self-initiated ED visit or other complications.

Study IV was a retrospective case-control study with 99 case patients that were readmitted within 90 days of primary elective TKA during a 1-year period. Planned readmissions and those clearly unrelated to the index procedure were excluded. Patients undergoing MUA were coded as inpatients in the hospital database. However, these were not included in the present study because the indication varies considerably by surgeon and because many MUAs were performed towards the end of the 90-day period and would possibly skew the results if included.

The readmission rates were calculated as the total number of readmissions divided by the number of patients undergoing TKA.

After screening via exclusion criteria, 60 patients remained for the risk factor analysis, in which the 60 readmitted patients were compared to a control cohort of randomly selected non-readmitted patients in a 1:4 ratio. The medical records provided readmission reasons, data on the index surgery and possible revision surgeries, laboratory results, and general patient demographics (age, gender, ASA score, BMI). Knee Society Score (KSS) and most of the individual elements graded in the KSS were also recorded.

4.3 FAST TRACK PROTOCOL AND PAIN MEDICATION

The study institution implemented a fast track protocol in 2009. The protocol includes informing the patients with both oral and written information before surgery. Patients can also choose to attend patient lectures that are given on a regular basis. All patients routinely receive local infiltration analgesia (LIA), which contains ropivacaine, adrenalin, and ketorolac. Tourniquets are used in TKA surgeries. All patients mobilise on the day of surgery with the help of a physiotherapist. The patients then receive physiotherapy twice daily until discharge or until mobilisation is at an acceptable level. Stair training is mandatory if there are stairs at home. The prevailing goal during the study period was discharge on the second or third postoperative day.

The postoperative pain medication protocol consisted of 1000 mg paracetamol and 600 mg ibuprofen, both given three times a day. Oxycodone was given on the day of surgery and on the first day after surgery. Starting on postoperative day 2, oxycodone was changed to weak opioids, namely one or two tablets of paracetamol/codeine 500 mg/30 mg one to three times daily. Patients who tolerated codeine poorly received long-acting tramadol 75 to 150 mg twice daily instead.

Patients were discharged when the following criteria were met: the patient is able to dress and go to the bathroom without assistance, walk a short distance, walk stairs (if stairs at home), pain is under control without strong opioids, and the wound does not bleed.

4.4 EMERGENCY RESPONSE TEAM AND ICU (STUDY I)

The ERT began activities in the arthroplasty ward in 2013. The team consists of one anaesthesiologist and one nurse that usually work in the ICU. The ERT service also includes training for the medical staff on the ward. They are educated on how and when to trigger the ERT, i.e. which criteria to monitor. To facilitate emergency interventions such as resuscitation and endotracheal intubation, the ERT team brings drugs and equipment that are not always available in the ward.

The ICU has six beds and is located in the same building as the arthroplasty unit. The staffing is constant 7 days a week. The ICU offers invasive monitoring and invasive mechanical ventilation. However, it does not offer dialysis and is therefore classified as a level II ICU according to the American College of Critical Care Medicine guidelines (Haupt et al. 2003).

Table 6 shows the ERT call criteria, which are similar to published recommendations (Cretikos et al. 2006). Apart from the "worried" criterion, several criteria at once could trigger the same ERT activation.

4.5 STATISTICAL ANALYSES

An independent biostatistician performed all statistical analyses in **Studies II** and **IV** using SAS System for Windows, version 9.4 (SAS Institute, Cary, NC). *P*-values <0.05 were considered statistically significant in all studies.

Studies I and **III.** As the studies were mostly descriptive in nature, the designs of these studies did not demand any extensive statistical analyses. Values are reported as percentages, mean (range), or median (interquartile range [IQR]) where appropriate.

Study II. To investigate potential risk factors for LOS longer than 3 days, all variables were first analysed with univariate logistic regression. Variables with a *P*-value <0.10 in the univariate analyses were investigated further in the multivariable analysis. All variables were checked for multicollinearity and correlating variables ($r \geq 0.50$) were excluded from further analyses. Two different models were built, one with the Knee Society (KS) knee and functional total scores and one with the individual elements from the KS scores (e.g. knee flexion, use of walking aids). Area under curve analysis provided means for choosing the best model. A stepwise forward procedure was used to build the multivariable models (inclusion criterion $P < 0.05$, exclusion criterion $P \geq 0.05$). Results are described with odds ratios (OR) and their 95% confidence intervals (CI).

To estimate the effect of the risk factors on LOS, the mean LOS for the different independent risk factors was determined. LOS was skewed to the right, thus geometric mean was used instead of arithmetic mean.

Study IV. When comparing demographic characteristics in the two groups, a chi-square test was used for categorical variables and a two-sample *t*-test was used for normally distributed variables. The Mann-Whitney U test was used for non-normally distributed data (CRP, INR, and LOS). Potential risk factors for readmission were investigated with logistic regression analysis. Variables with a *P*-value <0.10 in the univariate analyses were entered into a multivariable logistic regression model using a forward stepwise procedure (inclusion criterion $P < 0.05$, exclusion criterion $P \geq 0.05$). Four risk factors were entered into the final multivariable model. Results are described with OR and 95% CI.

5. RESULTS

5.1 STUDY I: OUTCOMES OF ERT ACTIVATION

Sixty-five ERT activations (61 patients) occurred during the study period. The ERT call incidence was approximately 7 per 1000 arthroplasty patients. The average age of the patients with an ERT call was 72 years (range 46–92). Sixty-two percent of the patients were female. The median LOS was four days (IQR 5). Most of the calls were received during daytime, and 13 calls (20%) were received during the night.

Nine out of ten patients underwent arthroplasty surgery during the same admission as the ERT call. Of these, 19 were primary THA, 12 revision THA, 17 primary TKA, and 8 revision TKA. The patients that did not have surgery were in the ward primarily because of treatment for periprosthetic joint infection.

Table 6 lists the ERT call criteria together with frequencies and percentages.

Table 6. ERT call criteria leading to ERT call, all patients.

ERT call criteria, as displayed on ERT form		ERT calls with criterion met, n, %[a]	
Ventilation	Airways at risk	2	3.1%
	Breathing frequency < 8/min	0	0%
	Breathing frequency > 28/min	5	7.7%
	SpO_2 < 90% with oxygen	24	36.9%
Circulation	Systolic blood pressure < 90 mmHg repeatedly	15	23.1%
	Heart rate < 40/min	3	4.6%
	Heart rate > 140/min	4	6.2%
Neurologic	Acute reduction of consciousness	22	33.8%
	Repeated or prolonged seizure	0	0%
Other	Worried (without any objective criteria met)	12	18.5%
	Severe pain	3	4.6%
	Diuresis < 150 ml/6 hours	2	3.1%

[a]For some calls, several criteria were met.

SpO_2, peripheral capillary oxygen saturation. *Reprinted with permission. Saku et al. Outcomes of Triggering the Emergency Response Team at a High-Volume Arthroplasty Center. Scand J Surg 2019 (in press). Copyright SAGE publications (2019).*

Figure 2 shows a flow chart of the ERT outcomes. Twenty-nine patients (45%) required admission to the ICU directly following ERT intervention. The ICU admission occurred most commonly due to respiratory problems, reduction in consciousness, and haemodynamic instability. In the ICU, 10 patients required norepinephrine infusion, 6 patients ventilatory support, and 11 patients invasive arterial pressure monitoring.

For the patients that remained in the ward, the most common interventions performed by the ERT were ordering laboratory tests (n = 25, 71%), changes to medication (n = 19, 54%), fluid resuscitation (n = 19, 54%), and oxygen therapy (n = 8, 23%). Naloxone, furosemide, and oxycodone were the most commonly administered drugs.

On retrospective assessment, a cause for the patient's deterioration was established in 54% of the cases. The most common causes were medication side effects (12%), pneumonia (8%), pulmonary embolism (8%), and sepsis (6%).

Of all study patients, 33 (54%) could be discharged directly home, 23 (38%) required discharge to further care, and 5 (8%) died during the hospital stay. Three percent of all ERT calls required no intervention.

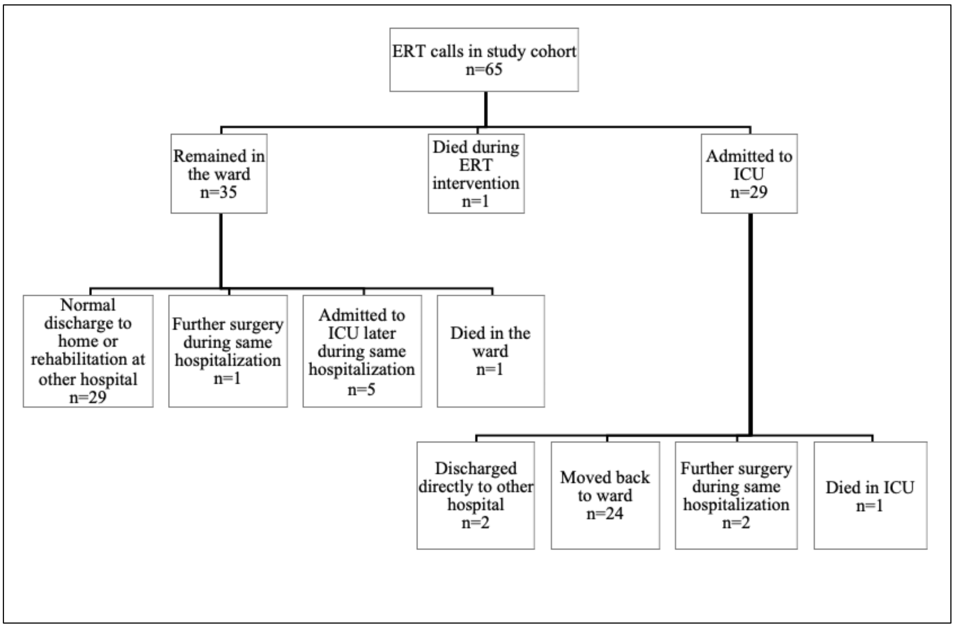

Figure 2. Flow chart of ERT call outcomes. *Reprinted with permission. Saku et al. Outcomes of Triggering the Emergency Response Team at a High-Volume Arthroplasty Center. Scand J Surg 2019 (in press). Copyright SAGE publications (2019).*

5.2 STUDY II: REASONS AND RISK FACTORS FOR DELAYED DISCHARGE FOLLOWING PRIMARY TKA

Of all 849 patients that received a primary TKA during the study period, 190 patients were discharged later than on the third postoperative day. The average age for all patients was 67.7 years and 68% were female. Ninety-one percent of the patients had spinal anaesthesia and the remainder had general anaesthesia. Demographical and clinical characteristics are presented in **Table 7**.

Table 7. Demographical and clinical characteristics for patients with normal vs delayed discharge.

Variable	**All patients**	**LOS ≤ 3 days**	**LOS > 3 days**
N	849	659	190
LOS (days)	3.15 (1, 15)	2.57 (1, 3)	5.17 (4, 15)
Age (years)	67.7 (33, 93)	66.0 (33, 92)	73.2 (41, 93)
BMI (kg/m^2)	29.7 (15.8, 47.8)	29.8 (16.4, 46.7)	29.5 (15.8, 47.8)
Gender, % female	67.8%	65.6%	75.8%
Preoperative ASA score			
1-2	37.8%	44.8%	13.7%
3-4	62.2%	55.2%	86.3%
KS functional score	55.6 (0, 100)	58.9 (0, 100)	44.4 (0, 100)
KS knee score	36.0 (0, 90)	36.9 (0, 90)	33.2 (0, 85)
Duration of surgery	97.2 (50, 309)	95.7 (50, 218)	102 (53, 309)
PACU time (h)	2.12 (0.0, 6.2)	2.06 (0.10, 6.20)	2.34 (0.0, 5.50)
Spinal anaesthesia	91.0%	93.0%	84.2%

Values reported as mean (range) or percentage. *Reprinted with permission. Saku et al. Reasons and Risk Factors for Delayed Discharge After Total Knee Arthroplasty Using an Opioid-Sparing Discharge Protocol. J Arthroplasty. 2019;34(10):2365-70. Copyright Elsevier (2019).*

The univariate analysis identified the following 14 variables that were significantly associated with delayed discharge: age (*P* < 0.001), gender (*P* = 0.008), ASA score (*P* < 0.001), preoperative walking distance (*P* < 0.001), preoperative use of walking aids (*P* < 0.001), preoperative ability to climb stairs (*P* < 0.001), tibiofemoral angle (*P* = 0.002), preoperative knee pain (*P* = 0.005), KS functional score (*P* < 0.001), KS knee score (*P* = 0.014), type of anaesthesia (*P* < 0.001), day of surgery (*P* = 0.010), duration of surgery (*P* = 0.007), and time spent in post-anaesthesia care unit (PACU) (*P* = 0.026).

In the final multivariable model, seven risk factors proved to be independent predictors of LOS longer than 3 days (**Table 8**). **Table 9** shows an estimation of the effect of the independent risk factors on LOS.

Table 8. Independent risk factors for delayed discharge according to the final multivariable regression model.

Risk factor		**OR (95 % CI)**	***P*-value**
Age			<0.001
vs < 60	60–64		0.909*
	65–69		0.197*
	70–74		0.111*
	75–79	2.74 (1.39 – 5.37)	0.003
	≥80	7.99 (3.97 – 16.1)	<0.001
ASA score	3–4	3.18 (1.95 – 5.18)	<0.001
Walking distance			<0.001
vs > 1 km	500–1000m		0.294*
	< 500m	2.05 (1.27 – 3.32)	0.004
	Housebound or unable	4.33 (2.17 – 8.63)	<0.001
Anaesthesia type	General	3.00 (1.67 – 5.37)	<0.001
Duration of surgery (min)		1.01 (1.00 – 1.02)	0.007
Time spent in PACU (h)		1.39 (1.13 – 1.70)	0.002
Day of surgery vs Mon-Tue	Wednesday through Friday	1.57 (1.06 – 2.33)	0.026

*non-significant. *Reprinted with permission. Reasons and Risk Factors for Delayed Discharge After Total Knee Arthroplasty Using an Opioid-Sparing Discharge Protocol, Saku et al., J Arthroplasty. 2019;34(10):2365-70. Copyright Elsevier (2019).*

Table 9. Estimation of how significant independent risk factors affect LOS compared to the lowest-risk group.

Risk factor		Mean LOS*	LOS change*
Age	< 60	2.61	
	75-79	3.08	+0.47 (18%)
	≥80	3.81	+1.20 (46%)
ASA score	1-2	2.56	
	3-4	3.16	+0.60 (23%)
Walking distance	> 1 km	2.63	
	< 500 m	3.14	+0.51 (19%)
	Housebound or unable	3.92	+1.29 (49%)
Anaesthesia	Spinal	2.89	
	General	3.29	+0.40 (14%)
Duration of surgery**	≤ 120 min	2.88	
	> 120 min	3.10	+0.22 (7.6%)
Time spent in PACU**	≤ 3 h	2.86	
	> 3 h	3.29	+0.43 (15%)
Day of surgery	Monday to Tuesday	2.81	
	Wednesday to Friday	2.99	+0.18 (6.4%)

* LOS reported as geometric mean and change (%) from lowest-risk group

** Variable analysed as continuous in multivariable analysis and split into groups to improve the readability of this table. *Reprinted with permission. Reasons and Risk Factors for Delayed Discharge After Total Knee Arthroplasty Using an Opioid-Sparing Discharge Protocol, Saku et al., J Arthroplasty. 2019;34(10):2365-70. Copyright Elsevier (2019).*

Upon retrospective review, a medical cause for delayed discharge was found in 80% of the cases. The most common reasons were delayed functional recovery (n = 59, 31%), pain (n = 22, 12%), fever or suspected infection (n = 9, 5%), and wound drainage (n = 8, 4%). The most common non-medical reasons were the patient's own wish to stay (n = 15, 8%) and waiting for PT or discharge to further care (n = 4, 2%).

5.3 STUDY III: PATIENT CONCERNS AFTER TJA AND THE USEFULNESS OF A PHONE CONSULTATION SERVICE

Two hundred eighty-eight phone calls from 185 individual patients were included in the study (**Figure 3**). The average age of patients calling was 67.6 years and 64% were female. Fifty-seven percent of the patients had undergone TKA surgery and 43% had undergone THA surgery. Ninety percent of the arthroplasties were primary and 10% were revision surgeries. The calls were made on average 20 days after discharge.

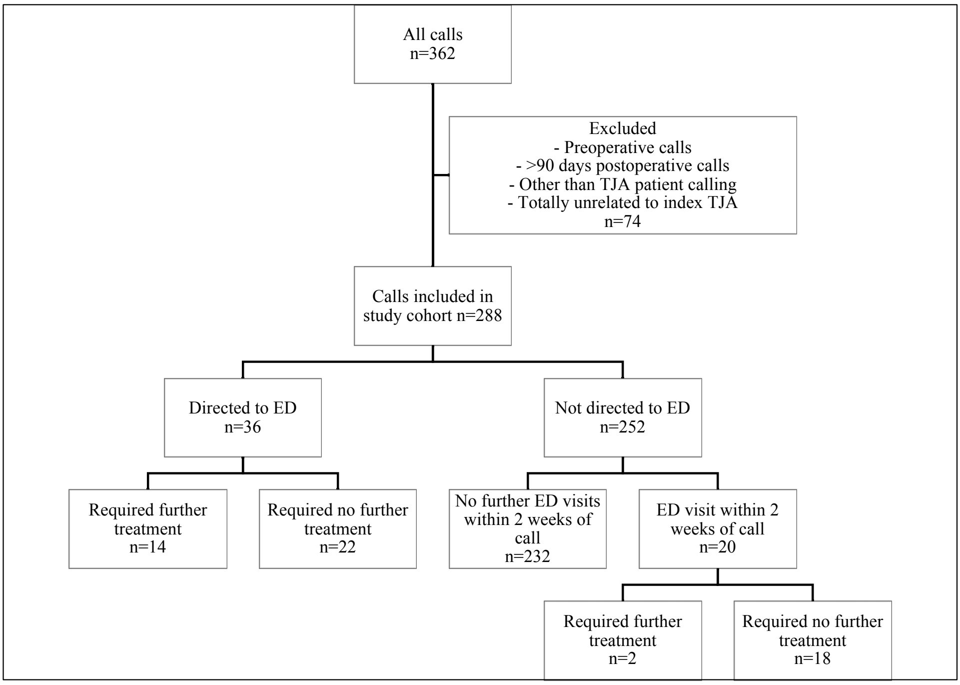

Figure 3. Flow chart of study patients (III). *Reprinted with permission. Hällfors et al. A Consultation Phone Service for Patients with Total Joint Arthroplasty May Reduce Unnecessary Emergency Department Visits. J Arthroplasty 2018;33(3):650-54. Copyright Elsevier (2019).*

Table 10 lists the call reasons. Medication-related concern was the most common call reason. Of these calls, 28% were related to insufficient pain medication, 27% were related to the use of prescribed medications, and 13% had to do with anticoagulation medication. Almost half of the wound-related questions (44%) were miscellaneous questions about wound care and 41% were due to infection suspicion. TKA patients called nearly twice as often as THA patients for medication-related concerns.

Table 10. Call reasons per category*.

Call reason	n, all calls	% of calls	n, patients instructed to visit ED	n, calls by TKA patients	n, calls by THA patients
Medication	128	41	3	84	44
Wound problem	53	17	17	28	25
Mobilization	46	15	2	25	21
Oedema	34	11	7	16	18
Miscellaneous reasons	13	4	3	5	8
Questions about paperwork	10	3	0	8	2
Haematoma	9	3	0	3	6
DVT suspicion	7	2	4	4	3
Question about outpatient visit times	6	2	0	3	3
Laboratory result inquiries	5	2	0	2	3
Constipation	2	1	0	1	1

*One patient call can be categorized as more than one call reason

The actions taken to resolve the patient concerns are shown in **Figure 4**. The answering nurse alone resolved two thirds of all calls. Every fourth patient that had undergone revision TJA was directed to the ED, compared to 10% of those who had undergone primary TJA. In total, 36 patients were instructed to visit the ED.

Fourteen of the patients directed to the ED (4.9% of study patients) received a diagnosis requiring treatment. This included three deep vein thromboses (DVT) and five surgical site infections (SSI) (three superficial wound infections and two PJIs). Of the patients not instructed to visit the ED, 20 still did so within 2 weeks of the call. Only two of these patients required any kind of treatment. Both were primary THA patients that developed a SSI and were treated with intravenous antibiotics and debridement surgery.

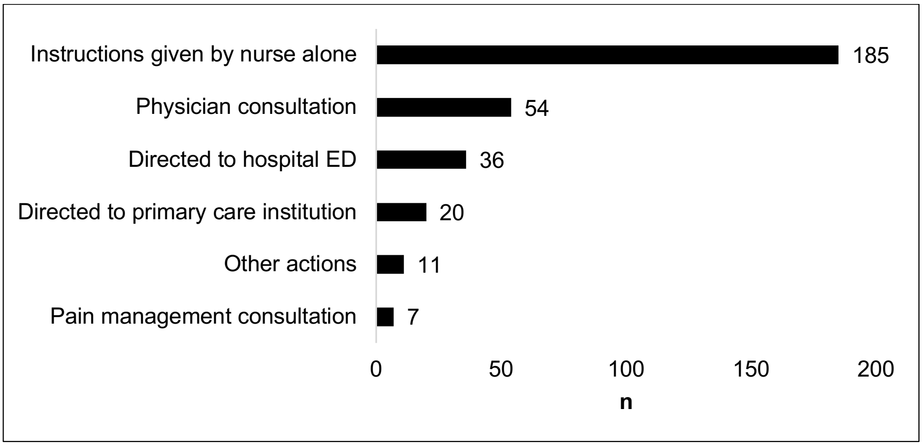

Figure 4. Actions taken to resolve the patient concerns. One call might have led to more than one action. *Reprinted with permission from Hällfors et al. A Consultation Phone Service for Patients with Total Joint Arthroplasty May Reduce Unnecessary Emergency Department Visits. J Arthroplasty 2018;33(3):650-54. Copyright Elsevier (2019).*

Table 11. Characteristics of readmitted patients and control cohort of non-readmitted patients (**Study IV**).

Variable	**Readmitted (n=60)**	**Control cohort (n=228)**	***P*-value**
Age (years)	69.9 ± 9.9	67.1 ± 9.8	0.052[b]
Gender (% female)	60.0	64.5	0.52[a]
BMI (kg/m²)	29.9 ± 4.9	29.6 ± 5.2	0.66[b]
Preoperative ASA score (%)			0.058[a]
1–2	25.0	38.2	
3–4	75.0	61.8	
Preoperative KSS	85.2 ± 32.6	92.3 ± 31.3	0.12[b]
Primary hospital length of stay (days)	3.6 ± 2.0	3.1 ± 1.3	0.16[c]
Duration of surgery (min)	100.4 ± 32.8	96.2 ± 26.9	0.30[b]

Values are reported as mean ± standard deviation or percentage.
[a]Chi-square test, [b]Two-sample t-test, [c]Mann-Whitney U-test.
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5.4 STUDY IV: REASONS AND RISK FACTORS FOR 90-DAY READMISSION AFTER PRIMARY TKA

The all-cause readmission rate was 6.9% (n = 61) within 30 days and 13.1% (n = 116) within 90 days after discharge. After excluding planned readmissions and those clearly unrelated to the index procedure, the readmission rates were 6.5% (n = 58) at 30 days and 8.0% (n = 71) at 90 days after discharge. **Table 11** shows demographic data for the study population.

The 71 readmissions within 90 days of discharge occurred in 60 individual patients. **Table 12** lists the 10 most common causes for unplanned readmission. Surgical reasons accounted for 68% and medical reasons for 32% of all readmissions. The most common surgical reasons for readmission were infection, knee pain, and haematoma. For medical readmissions, the most common reasons were gastrointestinal issues, cellulitis, and cardiovascular events.

Table 12. Ten Most Common Reasons for Unplanned 90-day Readmissions.

Reason	N	% of readmissions
Infection	21	29.6 %
Knee pain	10	14.1 %
Gastrointestinal-related	6	8.5 %
Haematoma	6	8.5 %
Wound drainage	5	7.0 %
Cellulitis	4	5.6 %
Cardiovascular event	3	4.2 %
Periprosthetic fracture	3	4.2 %
Other fracture	3	4.2 %
Pneumonia	2	2.8 %
Total no. of readmissions	71	100.0 %

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Univariate logistic regression analysis revealed nine variables that were significantly associated with readmission. These were number of drugs used (P = 0.003), asthma (P = 0.007), preoperative tibiofemoral valgus angle (P = 0.020), preoperative knee flexion less than 110° (P = 0.040), hypertension (P = 0.017), psychiatric disease (P = 0.010), epilepsy (P = 0.031), use of walking aids (P = 0.041), and LOS (P = 0.046).

In the final multivariable model, four variables remained significant. These independent risk factors are listed in **Table 13**.

Table 13. Independent risk factors for 90-day readmission after TKA.

Risk factor	OR (95 % CI)	*P*-value
Asthma	2.50 (1.20–5.21)	0.015
Preoperative knee flexion < 110°	2.03 (1.08–3.81)	0.027
Preoperative tibiofemoral angle of 11–15° (vs 5–10°)	2.67 (1.04–6.89)	0.042
Psychiatric disease	3.20 (1.26–8.11)	0.014

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6. DISCUSSION

6.1 OUTCOMES OF ERT ACTIVATION

This study showed that employing an ERT is a feasible way to address deteriorating arthroplasty patients. To the best of our knowledge, this is the first study that describes the outcomes of ERT activation in an arthroplasty-only patient population. Previous ERT studies have mostly focused on risk factors for ICU admission or death and thus failed to provide reasons for the emergency and reasons for ICU admission.

The ERT activation rate seems to vary considerably between different hospitals, with studies reporting rates of 2, 8, and 40 calls per 1000 admissions (Baxter et al. 2008, Weingarten et al. 2012, Silva et al. 2016). The rate of 7 per 1000 admissions in the present study is consistent with these previous reports.

The most common criteria triggering the ERT call seem to be similar in medical and surgical patients. The most common reasons include reduction in consciousness, hypotension, and airway problems (Young et al. 2008, Silva et al. 2016). According to the present study, this also seems to be the case for arthroplasty patients.

In many studies, the subjective criterion "worried about the patient" is also a common ERT trigger. It can be argued that the opportunity to make an ERT call based on a such subjective criterion might lead to a higher rate of unnecessary calls. However, at least in the present study, this was not a concern as 97% of the calls required interventions. The individual threshold for when to trigger the ERT using the "worried" criterion likely varies considerably. It may well be that the least experienced nurses make the call at a lower threshold. However, especially for more experienced nurses, the possibility to make an ERT call based on a subjective feeling that the patient is unwell likely has a positive overall effect. This possibility ensures that any approaching emergency that does not yet affect the objective criteria can be caught in time and is not overlooked. On the other hand, a study evaluating the effect of transitioning to automated supervision of ERT call criteria revealed that although the number of ERT calls increased, the outcomes improved (Subbe et al. 2017). In this study, there was understandably no "worried about the patient" criterion.

According to the ERT call criteria, all study patients had a potentially life-threatening condition. Still half of the patients could be treated at the arthroplasty ward thanks to the ERT intervention. Because of the study setting, it is impossible to conclude whether the ERT actually reduced the amount of unplanned ICU admissions, but it seems plausible that there was a positive effect. This hypothesis is supported by findings in other studies (Dacey et al. 2007).

Some of the ERT calls could have been addressed by the attending ICU physician alone, possibly as a consultation without triggering the ERT. This could be true especially for the calls where ordering laboratory tests and changing the medication were the only interventions needed. However, it is acceptable to have some calls that require only minor interventions, as having a threshold too high for ERT activation could lead to missing some real emergencies. The converse is also likely, in that there are ICU consultations that are made without triggering the ERT. However, the amount of these consultations is unknown and difficult to quantify.

Two recent studies on TJA patients investigated the reasons for requiring critical care services and interventions needed at the ICU (Memtsoudis et al. 2012, Courtney et al. 2015). These studies reported that cardiac and pulmonary complications were the most common reasons for requiring critical care after TJA, and that ventilation support and administering vasopressors were the most common interventions performed at the ICU. The results in the present study are consistent with this, as respiratory insufficiency and haemodynamic instability were the most common reasons for ICU admission.

The reasons for patient deterioration in the present study were partially different from what has previously been reported as common major postoperative concerns after TJA. Pulmonary embolism (PE), tachyarrhythmia, and myocardial infarction were listed as the most common major systemic complications in one study (Pulido et al. 2008). PE was very rare in our study, which may be related to different types of anticoagulation medication and earlier mobilization. Pulido and colleagues used warfarin for anticoagulation; the patients in the present study received mainly enoxaparin as thromboprophylaxis.

Although a low number overall, it should be noted that one ninth of the emergencies in the present study were caused by a drug-related side effect. These were related to excessive sedation and hypotension and should be largely preventable.

6.2 DELAYED DISCHARGE AFTER TKA

6.2.1 Length of stay

Although some institutions have started to perform outpatient TJAs in selected patients (Pollock et al. 2016), most patients worldwide are still treated as inpatients and the most commonly reported LOS is between 2 and 4 days (**Table 1**). The LOS in the present study is consistent with other modern studies, especially since the patients were not discharged with strong opioids. Moreover, the main target during the study period was discharge on day 2 or 3 postoperatively; no TJAs were performed as outpatient procedures. One third of the patients were discharged on the second day and almost half on the third day after surgery, so most patients met the goal of a maximum LOS of 3 days. It may be possible to further reduce the LOS for these patients, but addressing the patients with delayed discharge instead will likely yield better results and greater cost savings.

6.2.2 Risk factors for delayed discharge

Most published studies report that higher age poses a significantly higher risk for delayed discharge (**Table 1**). The importance of age as a risk factor is further emphasized by the fact that TJAs are performed in increasingly older patients. One way to address this problem would be to automatically trigger a specialised "higher age" protocol when a certain age criterion is met (e.g. for those >80 years). The "higher age" protocol could include routine consultation with a geriatrician, a higher nurse-to-patient ratio at the ward, and perhaps older patients should predominantly have their surgery at the beginning of the week to avoid the additional "weekend effect". Patients with ASA scores 3–4 could also be assigned to a similar higher risk group and receive more extensive care and monitoring. Based on previous results and those of the present study, age is also an important (and easy) factor to adjust for in pay-for-performance healthcare systems.

Some studies have shown that patients that need some kind of walking aid have a longer LOS (Husted et al. 2008, Ong and Pua 2013). However, preoperative walking distance has not previously been investigated as a risk factor for delayed discharge. According to our analyses, walking distance is a better predictor for delayed discharge than the use of walking aids. The reporting of walking aids may also be less objective than walking distance as there are many different types of aids. In addition, in many cases the walking aid is only used occasionally, for example when walking longer distances. It is tempting to hypothesize that increasing the walking distance prior to surgery would reduce the risk of a late discharge, but this should be further studied in a randomized trial. There is, however, some evidence that strength training and similar "prehabilitation" can impact LOS. With the increasing use of health technology and activity trackers, walking distance could be used to automatically stratify patients into different risk groups prior to surgery. Activity trackers may also help in the follow up of patients during rehabilitation post-surgery (Twiggs et al. 2018).

General anaesthesia performed worse than spinal anaesthesia in the current study with regards to LOS. A Dutch study by Mathijssen and colleagues (2016), which also included almost 900 TKA patients, reported similar findings. Based on other previous studies, general anaesthesia also appears to increase the risk of complications such as infections and mortality (Moucha et al. 2016).

To our knowledge, the time spent in the PACU has not previously been identified as a risk factor for longer LOS. In large registry studies, this information is seldom available. The prolonged PACU time likely reflects certain anaesthesia complications, such as insufficient pain medication and poor oxygenation (Lunn et al. 2012). Prolonged PACU stay should function as a perioperative warning sign for delayed discharge, as these patients are more likely to have trouble mobilizing on the day of surgery. Enhanced mobilization efforts should be provided to this subgroup.

Day of surgery influenced LOS in some studies (Husted et al. 2008, Keswani et al. 2016, Newman et al. 2017) but not in others (Edwards et al. 2016). In the present study, there was a significant weekend effect with longer LOS for patients operated on later in the week. The weekend effect certainly varies considerably between institutions depending on weekend staffing and discharge routines. In one arthroplasty hospital in Denmark, surgeries are only performed from Monday through Wednesday, and the hospital is closed during the weekend (Husted et al. 2011). This kind of approach seems to be quite unique, but no doubt cost-effective provided that the surgery volume during these 3 days is enough to meet demand. This is unlikely a feasible solution for most institutions. Instead, the weekend routines should be improved. Physiotherapy is often not as easily available during the weekend as during the week and the amount of available surgeons or physicians is also heavily reduced. Although the nurses in the present study had the authority to discharge patients when discharge criteria are met, they might not feel confident enough in the absence of a physician. There are also less patients in the ward during the weekend and therefore lesser pressure to discharge patients. It should be possible to reduce the average LOS by using risk stratification tools to predict the LOS and schedule lower-risk patients towards the end of the week. In this way the absence of resources during the weekend would be less detrimental.

6.2.3 Reasons for delayed discharge

The reasons for late discharge in the present study were mostly medical (80%), but in one fifth of the cases there was some other non-medical reason. These other reasons should be preventable. The discharge should, for example, not be delayed due to the patient waiting for PT or because the patient simply wants to stay because of social reasons. Adequate planning should ensure that there are no logistical reasons for delaying discharge, and social issues should be addressed beforehand.

In a prospective study in Denmark (Husted et al. 2011), the most common reasons for not being discharged on time were dizziness, general weakness, and pain. As in the present study, every fifth discharge in Husted and colleagues' study was delayed because of a non-medical reason. The reduced staffing during the weekend may increase logistical difficulties and hence lead to later discharge.

Because most of the patients mobilize as expected and do not require extensive pain medication, it can be argued that instead of improving the pain medication and rehabilitation protocols further, high-risk subgroups should be targeted instead. By identifying these patients with a high risk of delayed discharge already when planning the surgery, the risk factors may be addressed and the patients can receive extra support and attention at the ward. This should yield more satisfactory results than a general slight improvement for everyone.

6.3 PATIENT CONCERNS AND THE USEFULNESS OF A CONSULTATION PHONE SERVICE

More than every third patient in this study called the consultation phone service due to medication-related questions. This was more common for TKA patients than THA patients and they usually asked about painkillers in particular. Many studies have focused only on major complications such as readmissions and hence these minor concerns that eventually may lead to an ED visit are largely unheard of in the literature. TKA patients usually have more pain-related issues than THA patients (Salmon et al. 2001, Plate et al. 2016), which was also the case in the present study. There seems to be a need for better patient education with regards to the use of prescribed medication. Many concerns in the present study were solved by just explaining how the drugs are intended to be used. The patients may not be receptive enough to all information provided at discharge due to heavy pain medication (Moriarty et al. 2011). One way to address this concern is to provide better preoperative education and more written instructions at discharge.

Many concerns in the present study were related to the surgical wound. Although these concerns may be difficult to address by phone, only one third of these patients were directed to the ED. To enhance the handling of these concerns, integration of telemedicine into the phone consultation system would be very beneficial. This way the wound could be assessed without the patient having to visit the ED.

The amount of mobilization-related concerns rose towards the end of the follow-up period and was most common during the second and third postoperative months. This may be attributable to unrealistic expectations regarding rehabilitation time and should be better managed during the preoperative education.

The nurse answering the phone could handle more than two thirds of the calls alone. This points to an effective utilization of resources and likely a reduced amount of unnecessary ED visits and reduced costs. One eighth of the patients received instructions to visit the ED; these patients mostly presented with wound issues and oedema. This is expected since some of the most common early complications after discharge are wound infections and deep vein thromboses (Sutton et al. 2016). It could be dangerous to miss the signs of such a complication, something that was fortunately uncommon in the present study (only two patients that should have been directed to the ED were not directed there, and both these patients had a SSI). The sensitivity and safety of the phone consultation service would likely improve with telemedicine or the possibility to send pictures; this would have likely caught these two cases of SSI.

In summary, this study showed that a phone consultation service is a feasible way to address patient concerns after TJA and that it likely reduces the amount of unnecessary ED visits. Pain management and especially instructions on how and when to use the pain medications should be improved to reduce some of the most common concerns. Patient education should also be improved.

Furthermore, it is important to provide the patients with written information on wound care and managing expectations of rehabilitation.

6.4 READMISSIONS AFTER TKA

6.4.1 Readmission rate

In this study, the rate of unplanned readmissions that were related or possibly related to the index surgery was 6.5% at 30 days and 8.0% at 90 days after discharge. Previous studies mostly report similar rates (**Table 2**). It is, however, difficult to compare readmission rates directly, as several different inclusion and exclusion criteria are used when deciding which readmissions to report. Some studies report all-cause readmissions, some report only unplanned readmissions, and some further exclude those readmissions that are clearly unrelated to the index procedure. The latter was done in the present study.

In large registry studies, it is difficult to evaluate the relationship between the index procedure and a readmission, as often only ICD codes are available. One way to circumvent this is to count only readmissions with a surgical reason that is directly linked to the index procedure, for example SSI and periprosthetic fracture. This way many readmissions that are related to the index procedure are caught. However, other reasons such as medical readmissions that can be related to the index procedure are missed. A myocardial infarction or a stroke that occurs 2 days after discharge may well be at least partly due to the preceding arthroplasty surgery. Cardiovascular events are indeed common reasons for readmission after TJA (Avram et al. 2014). To avoid these possible errors in the present study, the medical records were scrutinized to investigate whether a certain readmission was likely or possibly related to the index surgery or totally unrelated. This is of course not totally objective and possibly subject to some error, which is further discussed in the limitations section.

The structure of the healthcare and referral system in the Helsinki and Uusimaa region ensures that every patient can be tracked using a personal identification number and that all admissions to any hospital in the region are captured. Hence it is possible that the present study caught a higher percentage of readmissions than in some other studies and that the readmission rate is therefore higher than in some studies. Insurance status also affects the likelihood of readmission and probably also plays a role here. Most published single-centre studies have recorded only readmissions to the same hospital (Zmistowski et al. 2013, Avram et al. 2014, Ricciardi et al. 2017), while in the present study all admissions to any hospital in the region were identified.

Due to these particularities of the present and many other studies, the readmission rates are difficult to directly compare with other reported rates. It is therefore difficult to draw any direct conclusions based on readmission rates. A more uniform definition of readmissions is warranted to enable comparison between different institutions and healthcare systems worldwide.

6.4.2 Readmission reasons

Knee pain and SSI together accounted for almost half of the readmissions at 90 days after discharge in this study. Two thirds of the readmissions were due to surgical causes and one third due to medical causes, which is similar to previous reports (Saucedo et al. 2014, Ali et al. 2019).

Almost all studies report that infection (either superficial wound infection, PJI, or both, depending on how they are reported) is one of the most common reasons for readmission. Some studies report thromboembolic events as common reasons for readmission (Kurtz et al. 2016b, Ali et al. 2019). This is interesting, as thromboembolic events were rare in the present study. This discrepancy can be due to differences in study design or simply statistical variation, since the previously mentioned studies are large database studies with hundreds of thousands of patients. However, in a smaller study with 6400 patients (Saucedo et al. 2014), 3.4% of the readmissions at 90 days were due to thromboembolic disease, which is also higher than in the present study. The difference may therefore be better explained by differences in thromboprophylaxis or in routines for the management of patients with DVT. Although thromboembolic complications are mostly treated in an outpatient setting at our institution and therefore do not lead to a readmission, routines may vary between hospitals.

Pain is a common issue after TKA and is more common among TKA patients than among THA patients. In one study (Kelly et al. 2018), MUA is reported as a common reason for readmission. However, there were no readmissions for this reason as these readmissions were excluded in the present study.

In the present study, cardiovascular and gastrointestinal issues were common medical reasons for readmission. This is similar to the results reported by Kelly and colleagues (2018). In their study, constipation was counted as a surgical readmission, as opposed to the present study. Still, gastrointestinal problems were among the three most common medical reasons in their study.

As the total number of readmissions was quite small (71), pure chance can make the results differ from larger registry studies. On the other hand, the possible correlation between TKA surgery and readmission can be better evaluated and totally unrelated readmissions were not included.

6.4.3 Risk factors for readmission

Many different diseases are linked to a higher readmission rate. This is also shown in studies using the CCI (Voskuijl et al. 2014) and ASA score (Schaeffer et al. 2015) instead of individual comorbidities. Common diseases that increase the risk of readmission are diabetes, cardiovascular disease, and psychiatric disease such as depression (Saucedo et al. 2014, Raines et al. 2015, Klement et al. 2016).

In the present study, higher ASA score was not an independent risk factor for readmission. This may be due to the low number of patients compared to some other studies. However, psychiatric disease (primarily depression) was one of the independent risk factors identified in this study. Although depression is not investigated as often as many somatic diseases, there are some studies that specifically investigated the effect of depression on outcomes after TJA. Overall, these patients seem to perform more poorly compared to psychologically healthy patients (Gold et al. 2016, Klement et al. 2016). This highlights the need for more support for this patient group. They may need more meetings prior to the surgery, and better support during the recovery phase. Pain-catastrophizing behaviour should be identified early to allow for timely interventions to reduce the risk of longer hospitalization and readmissions. Psychiatric drugs may also interfere with the pain medication used in arthroplasty surgery and the surgeons are probably not very familiar with using psychiatric drugs. Hence, these patients may benefit from a preoperative psychiatrist visit and perhaps a psychiatrist consultation with regards to pain medication after the surgery.

Pulmonary diseases, especially chronic obstructive pulmonary disease, have been identified as risk factors for readmission after TJA (Raines et al. 2015). However, asthma has not been investigated extensively and has not been shown to increase the risk of readmission. It is therefore unclear whether the result in the present study, that asthma is an independent risk factor for readmission, is due to chance or if there is a true effect. The use of corticosteroids has been linked to an increased risk of readmission (Boylan et al. 2016). Although most asthmatic patients do not use steroids systemically, the use of systemic steroids is higher in asthmatic patients than in non-asthmatic patients. In the study by Boylan and colleagues, asthmatic patients made up 15% of the chronic systemic corticosteroid users. Future studies are required to determine whether there is a true effect of asthma on readmissions after TKA.

The association of mechanical axis issues and limited range of motion with readmission has not been investigated extensively. In the present study, both a valgus deformity and a knee flexion deficit were independent predictors of readmission. It is unclear how this affects the risk of readmission, but it is likely related to the higher complexity of these operations. A severe valgus deformity or poor knee flexion may require extensive soft tissue releases, thereby increasing the risk for pain, swelling, and mobilization-related issues. It can also be related to a lower preoperative mobilization level, which may predict a lower engagement in postoperative rehabilitation, and hence poorer outcomes with subsequent readmission. Interestingly enough, flexion deficit was a risk factor for readmission although MUA was excluded.

6.5 STRENGTHS AND LIMITATIONS OF THE STUDY

In **Study I**, there were sometimes several criteria that triggered the same ERT call, which can make it more difficult to interpret the results. The same applies for ICU admissions, which sometimes had two main reasons for the same patient. Due to the retrospective nature of the study, the exact reason for the patient's deterioration may be uncertain. To reduce the risk of error in this situation, only the cases where a clear causality was evident and mentioned in the medical records by a doctor were recorded.

The fact that half of the patients could be treated at the ward following ERT activation suggests that the ERT service had a positive effect on the amount of ICU admissions. However, the study design did not allow for a definite conclusion. Previous studies also supported the finding that an ERT service seems to lower ICU admission rates (Dacey et al. 2007, Baxter et al. 2008).

In both case-control studies (**II** and **IV**), the main strengths were the detailed and first-hand data that were available. Unlike larger registry studies, the medical records could be reviewed in detail to increase the accuracy for e.g. which readmissions to include and which to exclude. Payer status is also not a confounding factor, as all Finnish citizens have government insurance. The single-centre approach reduced the impact of possible inter-hospital differences, such as patient education, discharge, and pain management routines. The use of a personal identification number and the hospital referral system, together with the fact that the hospital database recorded admissions to any hospital in the region, enabled tracking of all patients for admissions to any hospital in the region. Therefore, a major flaw present in many single-centre studies was avoided.

Studies II and **IV** have similar limitations, mainly due to their retrospective nature. In both studies, the reason for delayed discharge and readmission were assessed by retrospectively viewing the medical records. Therefore, it is not entirely certain that the real reason was captured correctly. To minimize the risk of arriving at the incorrect reason, both the medical records and nurse records were scrutinized.

Furthermore, the estimation of risk factor effect on LOS in **Study II** is only intended to estimate the size of effect of the individual risk factors and may not be correct for individual patients. If a patient has several risk factors, the different estimates will also most certainly not add up in a 1:1 ratio. Rather, the compound effect is likely to be less.

In **Study IV**, the causality between index procedure and readmission was determined retrospectively. Furthermore, the decision of which readmissions to include and which to exclude may be somewhat subjective. Therefore, the all-cause readmission rates should be used together with the related-cause readmission rates when comparing the results with other studies.

In **Study III**, the true effect of how much the phone consultation service actually reduces ED visits remains unknown. Only the patients that called the consultation phone service were followed up and included in the study, and the number of patients that went directly to the ED without using the consultation phone service is therefore unknown. In particular, patients that had urgent concerns during night-time or during the weekend may have visited the ED directly instead of waiting for the next weekday when the consultation phone service was available.

6.6 FUTURE ASPECTS

National arthroplasty registries have improved considerably in the last decade. Data on revision rates and the type of implants used are now readily available for investigation. PROMs are also being incorporated into several different registries. However, a unified definition of readmission rate is absent. To enable comparison of the performance between different hospitals and different healthcare systems, the reporting of readmission rates should be uniform. The readmission rates should be as objective and easily accessible as possible, but also reflect the quality of care well. Reporting only surgical readmission rates that are defined according to strict criteria with ICD-10 codes could be a good option. Surgical readmissions have a high variability between both different hospitals and different surgeons, and thus reflect differences in quality (Bottle et al. 2018). Readmission rates should be reported to national arthroplasty registries to enable comparison both on a national and international level. In a large US study, there were striking differences in readmission rates between hospitals, with rates ranging from 0% to 32% at 90 days after discharge (Kurtz et al. 2016b).

Automating the ERT call system led to improved outcomes in a single-centre UK study (Subbe et al. 2017). More studies are still needed to verify these results, but the future clearly lies in more automated supervision systems that are available to the patient at all times. Perhaps even the thresholds for when to make an ERT call could be adjusted according to the patient's individual normal vital parameter values. For example, a systolic blood pressure of 90 mmHg is considerably poorer for a patient whose normal pressure is 170 mmHg than for a patient whose normal pressure is 110 mmHg. By customising the ERT call criteria in this way, both the sensitivity and specificity of the calls would improve. This of course requires some kind of automated electronic supervision system, but this is clearly the direction we are heading.

LOS is constantly decreasing and TJA is trending continuously towards outpatient surgery. However, it must be considered that some patients, often with identifiable and sometimes modifiable risk factors, have significantly longer hospitalizations than average. These patients should be identified early enough to enable possible interventions and the planning of a personalized fast track protocol. This way patients with, for example, expected postoperative mobilization issues could be treated earlier in the week. Accordingly, this would avoid the effect of fewer physiotherapy resources available during the weekend. The hospital ward utilization rate, which commonly varies considerably during the week (often due to the absence of planned surgeries during the weekend), could be made more uniform during the week if the surgical schedule was planned according to the patient's expected LOS. Scheduling based on each patient's expected LOS in this way should allow for more surgeries (i.e. more ward patients) without increasing the maximum ward capacity.

The incorporation of different risk stratification tools into daily clinical practice should be improved to enable optimal resource allocation. The increasing use of artificial intelligence, machine learning algorithms, and big data will provide more accurate forecasting of LOS, complications, and costs in the near future (Ramkumar et al. 2019). This a very interesting area of future fast track development.

The present study suggests that incorporating telemedicine into the consultation phone system would be beneficial. According to a recent study, 81% of US citizens now own a smartphone (Pew Research Center, https://www.pewinternet.org/fact-sheet/mobile/, accessed on 6 February 2020) and most of these phones probably have a front-facing camera. With an increasingly larger part of the population using smartphones and similar electronic devices, the incorporation of telemedicine should not be too challenging to implement. The cost for running the service would remain the same, except for the initial cost of developing a suitable software, if needed.

The recent development of smartwatches and activity monitors could also be of use in fast track arthroplasty. These monitors could enable better post-discharge follow up of patients, particularly their activity levels. Patients that move too little could be encouraged to move more (either by the watch itself or by healthcare personnel), or they could receive more physiotherapist appointments to assist with possible mobilization-related issues. A randomized controlled trial recently revealed that TJA patients that wore step counters and had a daily step goal walked significantly more than those without a step goal and daily feedback from the activity tracker (Van der Walt et al. 2018). As low preoperative walking distance (according to the present study) is an independent risk factor for delayed discharge, the activity monitors could also be used for automated preoperative risk stratification.

The present study raises some questions that call for additional future research. For example, what are the reasons that some patients require a longer time in the PACU? How much does a consultation phone service actually reduce the amount of ED visits? Is it indeed cost-effective? Can the accuracy of the consultation phone service be further improved by incorporating telemedicine? Can "prehabilitation", with a focus on increasing preoperative walking distance and range of motion, influence LOS and readmission rates? Answers to these questions are not provided by the present study, but investigating these hypotheses could unveil useful ways to further reduce the amount of deviations in TJA.

7. CONCLUSIONS

1. An ERT service is an effective way to address a rapid clinical deterioration in arthroplasty patients and likely reduces the amount of post-operative ICU admissions. The most common ERT triggers in arthroplasty patients are reduced level of consciousness, hypotension, and low oxygen saturation.

2. Independent risk factors for delayed discharge after primary TKA are age ≥75 years, ASA score ≥3, shorter preoperative walking distance, general anaesthesia, longer duration of surgery, longer time spent in PACU, and surgery later in the week. The discharge is most commonly postponed beyond 3 days because of delayed functional recovery and pain.

3. A nurse-driven phone consultation service is a beneficial way to address concerns after discharge in TJA patients and may reduce the amount of unnecessary ED visits. Patient concerns are commonly related to prescribed medication, especially painkillers. Although phone consultation service seldom fails to identify patients that require an ED visit, the service can be even further improved by incorporating telemedicine.

4. The 90-day readmission rate after primary TKA at Helsinki University Hospital is similar to that commonly reported. Readmissions occur mostly due to SSI and knee pain. Independent risk factors for 90-day readmission are psychiatric disease, asthma, a preoperative valgus malalignment, and a preoperative knee flexion deficit.

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