



## Enhanced recovery in usual health care improves functional recovery after total knee arthroplasty



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### ABSTRACT

**Background:** The success of total knee arthroplasty (TKA) is determined by an effective surgical procedure as well as a well-organized clinical care pathway. Research has shown that day-of-surgery mobilization decreases length of stay (LOS) and complication rates. We developed, implemented, and evaluated a new clinical care pathway for patients undergoing TKA, that included early mobilization, using ‘Lean Six Sigma (LSS)’, with the aim of accelerating functional recovery and reducing LOS.

**Methods:** Data derived from physical therapy reports and LOS were compared between the old (n = 85) and the new (n = 85) clinical care pathways for time to functional recovery (using the modified Iowa Level of Assistance Scale), LOS and joint-related readmission. Group differences were evaluated using Mann–Whitney and Chi-Square tests. The clinical care pathway was redesigned using LSS-methods.

**Results:** After implementation of the new pathway, median time to functional recovery improved from 4 (2–5) to 2 days (1–8) (P < 0.001) and LOS from 7 (5–11) to 4 days (3–12) (P < 0.001), joint-related readmission declined (3.5–2.4%) (P = 0.65).

**Conclusion:** Implementation of the new clinical care pathway accelerated functional recovery and reduced LOS for patients undergoing TKA. Future research should focus on having multiple discharge moments per day which might encourage patients to achieve functional recovery as soon as possible.

### Introduction

Total knee arthroplasty (TKA) is a common procedure in patients suffering from osteoarthritis of the knee (Kehlet, 2013). TKA has proved to be a cost-effective (Jenkins et al., 2013) and effective procedure for pain relief, enhancing physical functioning and quality of life (Shan et al., 2015). Although TKA patients experience a broad variety of physical health problems and challenges at home 2–3 weeks after hospital discharge (Specht et al., 2018; Szots et al., 2015), overall patient satisfaction is good (Zhu et al., 2017). The success of TKA is determined, not only by an effective surgical procedure, but also by a well-organized clinical care pathway (Dowsey et al., 1999; Lisi et al., 2017) that includes appropriate postoperative pain treatment (Kehlet, 2013) and early mobilization (Husted et al., 2008). Previous studies demonstrated that early mobilization on the day of surgery decreased complication rates (Zhu et al., 2017) and length of hospital stay (LOS) (Pelt et al., 2017).

Current interdisciplinary clinical care pathways reduce the LOS after TKA by using enhanced recovery protocols (Galbraith et al., 2018; Kehlet, 2013; van der Sluis et al., 2015). The advantages of enhanced recovery protocols after TKA are well documented from both the

perspective of improved patient outcomes (Dowsey et al., 1999; Kehlet, 2013) and the socio-economic perspective (Pelt et al., 2017). The number of reoperations and readmission rates after TKA also decrease when using enhanced recovery protocols (Zhu et al., 2017).

Over the last decade, successfully implemented enhanced recovery protocols have decreased the period of postoperative hospitalization to 2–4 days in patients undergoing TKA (Holm et al., 2014; Husted et al., 2011; van der Sluis et al., 2015). Although their clinical effectiveness depends on many factors, nursing staff and other caregivers are crucial to the success of enhanced recovery protocols (Brown and Xhaja, 2018). Transformations in routine care require support from all health care providers involved and, as a consequence of a reduced LOS, workload will be considerably intensified over a shorter time-period (Specht et al., 2015). Therefore, developments towards enhanced recovery can only be sustained by further adjusting the clinical care pathway for patients undergoing TKA and by collaboration within a dedicated team in which all health care providers are involved in the clinical care pathway.

The main rationale for implementing enhanced recovery protocols in joint recovery practice is that an improved and shorter recovery period is assumed to reduce the need for patients to stay in hospital and,

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**Table 1**

Description of the main elements of the clinical care pathways for patients undergoing total knee arthroplasty, before and after the 'Lean Six Sigma (LSS)' project.

	Old pathway, before LSS	New pathway, after LSS
Pre-operative care, after the patient decides to be scheduled for TKA		Physical therapist provides information on the importance of postoperative physical activity for recovery. Orthopedic surgeon provides information on importance of postoperative physical activity for recovery and long-term expectations after TKA.
Hospital admission	One day before surgery	On the day of surgery, except for patients scheduled for surgery at 8 am, who are still admitted one day before surgery.
Anesthesia	Epidural analgesia or femoral nerve block for 48 h with catheters.	Local infiltration analgesia (ropivacaine 2% 150 ml morphine-sulphate 5 mg, adrenaline 0.5 mg) in combination with spinal analgesia or general anesthesia.
Pain treatment		
Preloading	None	Started on the day of surgery: Paracetamol 1000 mg Gabapentin 300 mg (or 100 mg $\geq$ 70 years/creatinine 30–60 ml/min/1.73m <sup>2</sup> ) Naproxen 500 mg Gastric protector
Postoperative, during hospitalization	< 24–48 h after surgery: pain medication is not necessary due to femoral or epidural catheter pain medication. > 24–48 h after surgery: Paracetamol (6 $\times$ 1000 mg) Naproxen (2 $\times$ 500 mg) Oxycodone (prolonged-release, if necessary, 2 $\times$ 10 mg)	Gabapentin (2 $\times$ 300 mg or 2 $\times$ 100 mg depending on age and renal clearance) Paracetamol (4 $\times$ 1000 mg) Naproxen (2 $\times$ 500 mg) Oxycodone (immediate-release, if necessary 6 $\times$ 5 mg) Oxycodone (prolonged-release, 2 $\times$ 10 mg) Patient controlled analgesia as rescue Paracetamol (6 $\times$ 1000 mg, if necessary) Naproxen (2 $\times$ 500 mg, up to 3–4 weeks) Oxycodone (prolonged-release, if necessary for up to 10 days, 2 $\times$ 10 mg)
After discharge	Paracetamol (6 $\times$ 1000 mg, if necessary) Naproxen (2 $\times$ 500 mg, up to 3–4 weeks) Oxycodone (prolonged-release, if necessary for up to 10 days, 2 $\times$ 10 mg)	Paracetamol (6 $\times$ 1000 mg, if necessary) Naproxen (2 $\times$ 500 mg, up to 3–4 weeks) Oxycodone (prolonged-release, if necessary for up to 10 days, 2 $\times$ 10 mg)
Start of mobilization	One day after surgery	4 h after surgery
Physical therapy	Aim: achieving functional recovery on the fourth day after surgery. Frequency: once a day (30 min), until moment of discharge.	Aim: achieving functional recovery as soon as possible. Frequency: twice a day, until the patient recovers independence. <sup>a</sup>
Discharge planning	Scheduled on the fourth day after surgery (home), or on the sixth day (if discharged to rehabilitation center or nursing facility).	Discharge was scheduled as soon as possible (home), or on the third day after surgery (if discharged to rehabilitation center or nursing facility)
Discharge criteria	Achievement of functional recovery and completed medical treatment and lack of complications. <sup>b</sup>	Achievement of functional recovery and completed medical treatment and lack of complications. <sup>b</sup>

TKA: Total knee arthroplasty.

<sup>a</sup> In case planned discharge location is a rehabilitation center or nursing facility, patients only receive physical therapy once a day.<sup>b</sup> In case the patient is discharged to a rehabilitation center or nursing facility, functional recovery is not mandatory for discharge.

thus, reduce LOS. However, LOS is not only influenced by the patient's actual functional recovery, but also by logistic (Husted et al., 2011), cultural and personal factors (Husted et al., 2008). LOS is, therefore, not an ideal outcome measure to evaluate the effect of implementing enhanced recovery programs. However, outcome measures in enhanced recovery protocols after TKA mainly focus on LOS instead of functional recovery, which is a shortcoming of current knowledge. Our rationale for this study was to focus on a more appropriate main outcome measure: inpatient functional recovery after TKA, which indicates the ability of inpatients to ambulate and transfer independently.

In this paper, we describe the process of development and implementation of an enhanced recovery protocol, leading to a new clinical care pathway for patients undergoing primary TKA. Our aim was to study whether the 'Lean Six Sigma (LSS)' project was able to provide accelerated functional recovery and decrease LOS for patients undergoing primary TKA. Based on literature about enhanced recovery protocols for TKA, and on experiences in other Dutch hospitals, we hypothesized that the LSS project would enable a reduction in time to functional recovery by 0.5 days (Holm et al., 2014; van der Sluis et al., 2015) and LOS by 3 days (Malviya et al., 2011) for patients undergoing primary TKA.

## Methods

### Design and participants

Routinely collected data derived from patient reports were evaluated for patients undergoing primary TKA in an observational cohort study at the Maastricht University Medical Center, the Netherlands. Between April 2016 and November 2016, a step-by-step implementation of the LSS took place. Data on functional recovery and LOS were collected before and after the implementation of the LSS project. Before implementation, data were assessed over a total of 8 months, between February 2015 and April 2016 (old clinical care pathway), separated into two periods: from February 2015 to June 2015 and from February 2016 to April 2016. February 2015 was chosen because 'timed-up-and-go' data was integrated into standard care at that time, and February 2016 till April 2016 because this data was already manually exported from the hospital patient records system. To analyze the changes brought about by the implementation of the LSS project on functional recovery and LOS, data was collected over an 8-month period from November 2016 to June 2017. All patients undergoing TKA during those specific periods, were included in the study.

### Old clinical care pathway

Prior to implementation of the new pathway, the patient and orthopedic surgeon decided to schedule a TKA, the patient was scheduled

for preoperative screening by a specialist nurse and an anesthesiologist, to evaluate social and functional status. If indicated, the patient was signed up in advance for post-operative rehabilitation within a rehabilitation center to avoid discharge delay due to waiting lists. One day before surgery, patients were admitted to the hospital and screened by a physical therapist. During this screening, patients were informed about the inpatient rehabilitation program and their preoperative physical functioning was tested using the Timed-Up-and-Go (TUG) test (Podsiadlo and Richardson, 1991).

Patients underwent surgery with epidural analgesia or a femoral nerve block (FNB) (Uesugi et al., 2014) which managed pain up to 24–48 h after surgery. After 24–48 h, postoperative pain treatment was continued with paracetamol (6 × 1000 mg), naproxen (2 × 500 mg) and prolonged-release oxycodone (2 × 10 mg, if necessary) during hospitalization. After discharge, paracetamol (as long as necessary), naproxen (3–4 weeks) and prolonged-release oxycodone (maximum of 10 days) were continued. Physical therapy started the day after surgery with daily 30-min treatment sessions if muscle strength was fully recovered after the femoral nerve block. These sessions consisted of training for transfers, such as getting in and out of bed or chair and walking, to achieve functional recovery, and exercises in the sitting position to regain muscle power and improve the mobility of the affected knee.

Patients were given a target for discharge on the fourth day after surgery. Discharge took place when the patient met the discharge criteria: if functional recovery was achieved and if no complications had arisen. In case the patient was not able to return home safely, because of a lack of functional recovery or due to his or her social status, the patient was discharged to a rehabilitation center, aiming at discharge six days after surgery. In the preoperative phase, all health care providers involved in the care pathway disseminated information to the patient and their relatives with regard to discharge date and location. Table 1 describes the main elements of the clinical care pathways, before and after implementation of the LSS project.

### Intervention

The LSS project (Gwynne-Jones et al., 2017) was started with the aim of optimizing the care pathway leading to enhanced recovery; defined as accelerating functional recovery and reducing LOS for patients undergoing TKA. The LSS project consisted of 14 multidisciplinary meetings over a period of 23 months, with contributions from the multidisciplinary team of orthopedic surgeons, anesthesiologists, physical therapists and nurses. Employees from pharmacy, radiology, recovery room, surgery planning and the transfer staff were also present.

LSS is a method used to analyze and innovate processes systematically. It consists of five phases: (1) Define, (2) Measure, (3) Analyze, (4) Improve and (5) Control. These phases were applied during the whole process (Gwynne-Jones et al., 2017). According to these five phases; the problems were defined as an extended time before functional recovery after TKA was achieved and a prolonged LOS (1). Current measures on time to functional recovery and LOS were assessed in the old clinical care pathway (2). Subsequently, all elements and processes included in the clinical care pathway were evaluated for efficiency (3). Specific elements or processes which delay functional recovery or LOS after TKA were further investigated. Multiple elements which might delay the development towards functional recovery and the period of hospitalization were identified and addressed, including suboptimal analgesia techniques, postoperative mobilization and inefficient agreements on organization level towards hospital admission and discharge. Every meeting of the LSS project was dominated by one or more experienced problems in the current clinical care pathway, after which a plan of action was defined to solve the problems experienced in the existing clinical care pathway (4). During the next meeting, improvement actions were evaluated and adjusted if

necessary. This cycle was repeated until all defined problems were tackled, leading to a new clinical care pathway (5). The new clinical care pathway was fully implemented from November 2016.

The secondary aim of LSS was improved collaboration between all health care providers involved in the clinical care pathway concerning TKA, to make sure that their expectations of the enhanced recovery protocol were synchronized. As a result of their ownership of the LSS project and having the common goal of accelerating functional recovery, all health care providers on the orthopedic ward were motivated to respect the enhanced recovery protocol. Existing enhanced recovery protocols from other hospitals (Holm et al., 2014; Husted et al., 2011; Malviya et al., 2011; van der Sluis et al., 2015) were used as inspiration for development of an improved clinical care pathway.

### New clinical care pathway

Changes were introduced in the departments of anesthesiology and physical therapy and on the orthopedic ward to facilitate early mobilization in the new clinical care pathway and to overcome organizational shortcomings. Table 1 describes the main elements of the clinical care pathways before and after implementing the LSS project.

In the department of anesthesiology, improvements were implemented regarding treatment of postoperative pain. Preloading of pain medication was started on the day of surgery: patients received paracetamol (1000 mg), gabapentin (300 mg (or 100 mg ≥ 70 years/creatinine 30–60 ml/min/1.73 m<sup>2</sup>)), naproxen (500 mg) and a gastric protector. During surgery, the local infiltration analgesia (LIA, ropivacaine 2% 150 ml morphine-sulphate 5 mg, adrenaline 0.5 mg) technique was applied in combination with spinal analgesia or general anesthesia. Postoperative pain treatment during hospitalization was continued with gabapentin (2 × 300 mg or 2 × 100 mg depending on age and renal clearance), paracetamol (4 × 1000 mg), naproxen (2 × 500 mg), immediate-release oxycodone (6 × 5 mg, if necessary) and prolonged-release oxycodone (2 × 10 mg). In case the patient still experienced pain, patient-controlled analgesia, as rescue, was used for pain treatment. After discharge paracetamol (as long as necessary), naproxen (3–4 weeks) and prolonged-release oxycodone (maximum of 10 days) were continued.

Improvements in the department of physical therapy were also implemented. Patients were invited to come to the hospital a few days before surgery to be educated by a physical therapist about inpatient rehabilitation and the importance of postoperative physical activity for recovery. The goal was to increase patient's self-efficacy and to positively influence patient expectations, which was intended to lead to a reduced LOS and accelerated functional recovery (Yoon et al., 2010). In addition, the patients' preoperative physical functioning was assessed using the TUG (Timed Up and Go Test) (Podsiadlo and Richardson, 1991).

After surgery patients were mobilized within 4 h by the physical therapist if their medical status allowed this. From the day after surgery the physical therapist visited the patient twice daily for 20–30-min physical therapy sessions. Frequency of physical therapy was doubled compared to the old clinical care pathway in order to achieve functional recovery as soon as possible and to shorten LOS. Patients who were planned to be discharged to a rehabilitation center or nursing facility only received physical therapy once a day since accelerated functional recovery would not shorten LOS.

Various improvements were implemented in the orthopedic ward, particularly at the organizational level. Before hospital admission, patients received a specialized information packet, called 'My knee book' to give extra information about the whole process and to facilitate self-management of recovery. Patients were invited a few weeks to months before surgery for preoperative screening by a specialist nurse, to evaluate social and functional status. If necessary, the patient was signed up for a rehabilitation center in advance so that discharge would not be delayed as a result of waiting lists. Patients were admitted to the

**Table 2**  
Characteristics and outcomes of patients undergoing total knee arthroplasty in old vs. new clinical care pathway.

	Old clinical care pathway		New clinical care pathway		P-value
	n		n		
<b>Patient Characteristics</b>					
Age in years (median, range)	85	69.0 (47–86)	85	69.0 (52–86)	0.43
Sex (n male)	85	36	85	40	0.54
BMI in kg/m <sup>2</sup> (median, range)	85	28.4 (21.8–43.2)	85	28.7 (20.9–42.6)	0.56
TUG in seconds (median, range)	85	10.0 (5.9–26.6)	78	8.9 (4.7–23.4)	< 0.001
<b>ASA (n)</b>	85		85		0.40
1		15		9	
2		60		62	
3		10		13	
4		0		1	
<b>Outcomes</b>					
Days from surgery to achieving functional recovery <sup>a</sup> (median, range)	72 <sup>b</sup>	4.0 (2.0–5.0)	69 <sup>b</sup>	2.0 (1.0–8.0)	< 0.001
Days from hospital admission to achieving functional recovery <sup>a</sup> (median, range)	72 <sup>b</sup>	5.0 (3.0–6.0)	69 <sup>b</sup>	3.0 (1.0–8.0)	< 0.001
LOS in days (median, range)	85	7.0 (5.0–11.0)	85	4.0 (3.0–12.0)	< 0.001
Joint-related readmission within 90 days after TKA (n)	85	3	85	2	0.65
Discharge location (n):	85		85		0.39
Home		73		69	
Rehabilitation center or nursing facility		12		16	

BMI: body mass index; TUG: timed-up-and-go test; ASA: American Society of Anesthesiologists physical status classification; LOS: length of stay; TKA: total knee arthroplasty.

<sup>a</sup> Measured with the modified Iowa Level of Assistance Scale (score of 0 [or 6 stair climbing was not needed] indicates functional recovery).

<sup>b</sup> Missing cases on functional recovery due to referral of incompletely recovered patients who went to a rehabilitation center or nursing facility.

hospital on the day of surgery, except those scheduled for surgery at 8 a.m., who were still admitted the day before surgery.

Clear discharge criteria were defined and discussed preoperatively with patients and relatives to achieve realistic patient expectations (Bozic et al., 2013). Both patients, their relatives and all caregivers were familiarized with preoperative goal setting so that realistic expectations could be set. If a patient achieved functional recovery, completed the medical treatment, and no complications arose, the patient was allowed to be discharged home. Patients who were planned to be discharged to a rehabilitation center or nursing facility due to their preoperative social or functional status, were discharged 3 days after surgery, if medical treatment was completed and no complications had arisen.

As a result of the multidisciplinary involvement in the LSS project, multidisciplinary collaboration among all health care providers on the orthopedic ward was improved with respect to encouraging patients' physical activity (e.g., by spending time in the 'living room' on the orthopedic ward, having meals together with other patients) after TKA. Due to their feeling of ownership of the LSS project, and having the common goal to accelerate functional recovery, all health care providers involved in the orthopedic ward were motivated to encourage patients' physical activity level.

#### Outcome measures

To evaluate the new clinical care pathway, functional recovery (primary outcome), LOS and joint-related readmission (secondary outcomes) were assessed.

Functional recovery was assessed using the modified Iowa Level of Assistance Scale (mILAS) (Elings et al., 2018). The mILAS assesses a patient's ability to safely perform five activities of daily living (supine-

to-sit, sit-to-supine, sit-to-stand, walking and stair climbing) and rates the amount of assistance necessary. Each activity of the mILAS was scored on a scale with 7 response categories: 0 (independent), 1 (standby/supervision), 2 (1 point of contact), 3 (2 points of contact), 4 (3 or more points of contact), 5 (failed with maximal assistance), and 6 (not tested for medical reasons or for reasons of safety). Stair climbing was not routinely assessed, only for those who were required to climb stairs in their home. The mILAS has a maximum score of 30 and a minimum score of 0. Functional recovery was assumed to have been achieved if the patient had a score of 0 or 6, depending on the need for stair climbing. In case the patient was not in need of stair climbing at home, this activity was not performed during hospitalization and, for that reason, was assessed with a score of 6. Assessment of functional recovery was performed daily, starting within 4 h after surgery.

LOS was calculated as the number of days the patient remained admitted to the hospital. Joint-related readmission was assessed as hospitalization within 90 days after TKA due to complications related to TKA.

#### Statistics

Descriptive statistics were used to describe the study population and postoperative variables of interest. The Shapiro-Wilk test was performed to check for normally distributed data of the independent variable. Homogeneity of data was checked with Levene's test for homogeneity of variances.

The Mann-Whitney and Chi-Square tests were used to evaluate the differences between the two groups. Statistical significance was set at 0.05. The Statistical Package for the Social Sciences 23 (SPSS Inc., Chicago, IL) was used for the analyses.

Based on a power of 80%, a significance level of 0.05 (one-sided)

and an expected reduction of time to functional recovery of 0.5 days (Holm et al., 2014; van der Sluis et al., 2015), 20 patients were needed in both groups to detect an effect size of 0.83. Since adaptation of the clinical care pathway was part of routine care, group sizes were overpowered.

## Results

Data for all 170 patients who underwent primary TKA were analyzed: 85 patients were managed using the old clinical care pathway and 85 patients using the new pathway (no patients were excluded from the analyses). The preoperative characteristics and postoperative outcomes of the patients who underwent TKA in the old and the new clinical care pathway are presented in Table 2.

Preoperative patient characteristics (age, sex, BMI) in the old clinical care pathway did not differ to those of the patients who underwent surgery in the new pathway ( $P > 0.40$ , Table 2), except for TUG ( $P < 0.001$ , Table 2). In the new clinical care pathway 19% of the patients were discharged to a rehabilitation center compared to 14% in the old clinical care pathway ( $P = 0.40$ ). All patients were discharged to their pre-planned discharge location.

Data on recovery of physical function after surgery were collected for all patients in both the old and the new clinical care pathway. Eighty-five percent of the patients in the old clinical care pathway and 81% of the patients in the new clinical care pathway were discharged home and achieved full functional recovery, measured with the mLAS. The remaining patients did not achieve full functional recovery at hospital discharge since these patients were discharged to a rehabilitation center before reaching functional independence.

Median time to functional recovery improved from 4 days (2–5) in the old clinical care pathway to 2 days (1–8) in the new pathway ( $P < 0.001$ , Table 2), and LOS from 7 days (5–11) to 4 days (3–12) ( $P < 0.001$ , Table 2). In the old clinical care pathway, 3 patients (3.5%, due to persistent pain, leg edema and limited range of motion of the knee) were readmitted compared to 2 patients (2.4%, due to persistent pain and infection of the prosthetic) in the new clinical care pathway ( $P = 0.65$ , Table 2). All five patients were readmitted within the first 30 days.

## Discussion

Adjusting the clinical care pathway for patients undergoing primary TKA by implementing improvements in the departments of anesthesiology and physical therapy and on the orthopedic ward, using LSS, led to an acceleration of functional recovery by two days and a clinically relevant reduction of LOS by three days.

Our results are in line with previous studies at units which also implemented enhanced recovery protocols in a multidisciplinary setting. Several hospitals successfully enhanced (functional) recovery and reduced the period of postoperative hospitalization to 2–4 days for patients discharged home (Gayed et al., 2013; Holm et al., 2014; Malviya et al., 2011; van der Sluis et al., 2015).

A drawback of most previous studies was that they did not systematically use functional recovery as the outcome measure, instead using LOS (Gayed et al., 2013; Husted et al., 2008; Husted et al., 2011). It is well-known that LOS depends on more factors than functional recovery such as being influenced by logistic factors, like waiting for physical therapy (Husted et al., 2011), as well as cultural factors such as patient expectations (Halawi et al., 2015) and personal factors, such as living alone (Toh et al., 2017). In our study, overall functional recovery was achieved two days after surgery, whereas LOS remained four days. Hence, further improved coordination regarding functional recovery between all health care providers involved and discharge criteria might lead to a hospital discharge timing which is determined by the moment a patient achieves functional recovery (provided no medical issues are present). As a consequence, the economic benefit could be even larger:

a theoretical reduction of €282 per day would be obtained in our hospital.

A notable degree of discrepancy between functional recovery and LOS in the old clinical care pathway was detected. In our study, LOS was figuratively prolonged for approximately one-third of the patients, as they were admitted to the hospital one day before surgery so the degree of incongruence is enlarged. What contributed to the remaining discrepancy in our study is the fact that there is only one discharge moment a day, whereas physical therapists monitor the patient at least twice a day. van der Sluis et al. (2015) reported a high level of agreement between the moment at which functional recovery was achieved and the time of discharge. This might be a result of better communication among multidisciplinary staff, which suggests we still need improved coordination between all health care providers involved in the orthopedic ward. It should be considered that, as a consequence of a reduced LOS, workload will be considerably intensified in a shorter time-period (Specht et al., 2015). Therefore, a dedicated team of all health care professionals involved in the clinical care pathway is needed to achieve a successful transformation of the clinical care pathway. Future studies should assess compliance with this transformation. Another major cause of the lack of agreement between the moments of functional recovery and hospital discharge could be medical complications such as wound leakage. In our study, only joint-related readmission was monitored as a major complication. Since this type of complication will not delay LOS, future research should systematically monitor medical complications, including minor complications, during hospital admission.

To decrease the incongruency between time to functional recovery and LOS, we implemented changes to the clinical care pathway that included stricter communication among all health care providers involved and an adapted hospital admission policy. The difference decreased from two to one day in the new clinical care pathway.

Preoperative training of physical functioning and muscle strength is currently considered to be a suitable method to further reduce the duration of functional recovery after surgery and shorten LOS in patients at increased risk of delayed functional recovery. However, conflicting evidence is found for preoperative training in patients waiting for TKA. A meta-analysis in a non-selective group of patients waiting for TKA suggested that preoperative training, compared to usual care, was effective in reducing the length of stay after TKA (Chen et al., 2018). This finding is confirmed by Calatayud et al. (2017), who reported positive results with regard to LOS after eight weeks of preoperative training of a non-selective group of patients waiting for TKA. By contrast, the systematic review by Hoozeboom et al. (2012) demonstrated that the effectiveness of a validated exercise program in individuals awaiting TKA remains unconfirmed (Hoozeboom et al., 2012). Although Chen et al. (2018) and Calatayud et al. (2017) demonstrated reduced LOS, their period of hospitalization still exceeded the median LOS at our hospital. This indicates that a reduction in LOS requires more than improving a patient's physical functioning alone, and that multidisciplinary adjustments to the clinical care pathway are essential. Besides, it should be considered that the reductions in LOS might be a result of better organization and communication at the orthopedic ward after implementation of their preoperative program. Effective patient selection for preoperative training may also be important (Wynter-Blyth and Moorthy, 2017) with regard to treatment effectiveness, as some patients respond differently to non-pharmacological interventions than others (Wright et al., 2011). In the future, targeted preoperative training might be beneficial for a selected group of patients who are at (high) risk for delayed functional recovery and/or prolonged LOS. Furthermore, current developments are tending toward discharge one day after surgery (Berger et al., 2005), although opinions on this differ (Berger et al., 2009; Courtney et al., 2015; Lovald et al., 2014).

Our analysis of preoperative patient characteristics revealed baseline differences in TUG findings, and linear regression showed that TUG was associated with time to functional recovery ( $R = 0.33$ ) and LOS

( $R = 0.30$ ). However, both associations were negligible (Hinkle et al., 2003). Since improvements in the time to functional recovery and LOS were considerable, it is unlikely that this improvement can be explained by differences in TUG. Furthermore, outcomes for TUG show a decent overlap: TUG ranges from 5.9 to 26.6 s in the old clinical care pathway and from 4.6 to 23.4 s in the new clinical care pathway. Therefore, our baseline difference for TUG of 1.1 s should be considered as a non-clinically important difference.

Several strengths of this study are evident. This health care reform was carried out in regular practice, indicating that our new clinical care pathway could also be implemented at other orthopedic wards. Secondly, our main outcome was functional recovery, rather than LOS. LOS depends on other factors besides functional recovery and is, therefore, not an appropriate outcome measure to evaluate adjusted recovery programs. We suggest that future studies evaluating enhanced recovery programs should include a focus on functional recovery. Thirdly, referral to rehabilitation centers is very well organized at our hospital, both before and after implementation of the enhanced recovery protocol. Because of pre-planned discharge location, patients are signed up for a rehabilitation center in advance so that discharge would not be delayed as a result of waiting lists. As a result, some of the patients do not necessarily have to achieve full functional recovery in terms of mLAS scores before they can be discharged. It should be noted that for the majority of patients with pre-planned discharge to a rehabilitation center, the main reason was lack of social support rather than poor functional recovery. However, lack of social support could be solved by timely recognition of barriers to discharge home during preoperative screening. Barriers like preparing meals, support with personal care or housekeeping are solvable by domiciliary care. It should be considered that delayed discharge due to lack of social support, rather than poor functional recovery, could be a major issue in many hospitals.

This study also had some limitations. Firstly, the LSS project was a multidisciplinary project aiming to optimize the care pathway leading to enhanced recovery, defined as accelerated functional recovery and reducing LOS for patients undergoing TKA. The key to success in improving existing clinical care pathways is compliance of all health care providers involved. Although an important goal of the LSS project was to equalize staff expectations and to motivate the health care providers involved by creating a sense of ownership of the LSS project, compliance was not monitored. The most common barriers experienced during the LSS project were difficulties in changing the mindset of the health care providers on the orthopedic ward and execution of new and adapted agreements (including early mobilization, encouragement of physical activity and discharge when completing discharge criteria). Secondly, assessment of functional recovery was performed using the mLAS. Although the original version of the Iowa Level of Assistance Scale is a highly reliable, valid, and responsive measure for patients after TKA (Shields et al., 1995), the addition of a fifth activity (transfer from sit to supine) in this modified version could have affected the psychometric properties.

An option for the near future is to investigate possibilities for continuous hospital discharge throughout the day, to decrease the discrepancy between the moment of functional recovery and LOS. This might encourage patients to achieve functional recovery as soon as possible and offers economic benefits.

## Conclusion

We demonstrated that the development and implementation of a new clinical care pathway, using LSS, has accelerated functional recovery and reduced LOS for patients undergoing TKA. Our hypothesis that the LSS project was able to reduce time to functional recovery by 0.5 days and LOS by 3 days for patients undergoing primary TKA was confirmed. The benefits, in terms of accelerated functional recovery and reduced LOS, are likely to be attributable to intensified physical

therapy, appropriate pain treatment and improved collaboration among the multidisciplinary team. The LSS method proved to be a feasible tool to improve current clinical care pathways. Nevertheless, a key factor to successful transformations in routine care settings demands support from the all health care providers involved and that all those involved believe in the concept in order to achieve successful implementation of an enhanced recovery protocol. Finally, we showed that evaluation of a new clinical care pathway in health care is feasible in a routine care setting and should be encouraged.

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The institutional ethics committee declared this study did not require ethical approval (registration ID, 2017-0219, 10 November 2017). This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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## References

- Berger, R.A., Kusuma, S.K., Sanders, S.A., Thill, E.S., Sporer, S.M., 2009. The feasibility and perioperative complications of outpatient knee arthroplasty. *Clin. Orthop. Relat. Res.* 467 (6), 1443–1449.
- Berger, R.A., Sanders, S., Gerlinger, T., Della Valle, C., Jacobs, J.J., Rosenberg, A.G., 2005. Outpatient total knee arthroplasty with a minimally invasive technique. *J. Arthroplast.* 20 (7 Suppl. 3), 33–38.
- Bozic, K.J., Belkora, J., Chan, V., Youm, J., Zhou, T., Dupaix, J., Bye, A.N., Braddock 3rd, C.H., Chenok, K.E., Huddleston 3rd, J.I., 2013. Shared decision making in patients with osteoarthritis of the hip and knee: results of a randomized controlled trial. *J. Bone Joint Surg Am* 95 (18), 1633–1639.
- Brown, D., Khaja, A., 2018. Nursing perspectives on enhanced recovery after surgery. *Surg. Clin.* 98 (6), 1211–1221.
- Calatayud, J., Casaña, J., Ezzatvar, Y., Jakobsen, M.D., Sundstrup, E., Andersen, L.L., 2017 Sep. High-intensity preoperative training improves physical and functional recovery in the early post-operative periods after total knee arthroplasty: a randomized controlled trial. *Knee Surg. Sport. Traumatol. Arthrosc.* 25 (9), 2864–2872.
- Chen, H., Li, S., Ruan, T., Liu, L., Fang, L., 2018. Is it necessary to perform prehabilitation exercise for patients undergoing total knee arthroplasty: meta-analysis of randomized controlled trials. *Physician Sportsmed.* 46 (1), 36–43.
- Courtney, P.M., Rozell, J.C., Melnic, C.M., Lee, G.C., 2015. Who should not undergo short stay hip and knee arthroplasty? Risk factors associated with major medical complications following primary total joint arthroplasty. *J. Arthroplast.* 30 (9 Suppl. 1), 1–4.
- Dowsey, M.M., Kilgour, M.L., Santamaria, N.M., Choong, P.F., 1999. Clinical pathways in hip and knee arthroplasty: a prospective randomised controlled study. *Med. J. Aust.* 170 (2), 59–62.
- Elings, J., Zoethout, S., Ten Klooster, P.M., van der Sluis, G., van Gaalen, S.M., van Meeteren, N.L.U., Hoogbeem, T.J., 2019. Advocacy for use of the modified Iowa Level of Assistance Scale for clinical use in patients after hip replacement: an observational study. *Physiotherapy.* 105 (1), 108–113.
- Galbraith, A.S., McGloughlin, E., Cashman, J., 2018. Enhanced recovery protocols in total joint arthroplasty: a review of the literature and their implementation. *Ir. J. Med. Sci.* 187 (1), 97–109.
- Gayed, B., Black, S., Daggy, J., Munshi, I.A., 2013. Redesigning a joint replacement program using lean six Sigma in a veterans affairs hospital. *JAMA surgery* 148 (11), 1050–1056.
- Gwynne-Jones, D.P., Martin, G., Crane, C., 2017. Enhanced recovery after surgery for hip and knee replacements. *Orthopedic nursing* 36 (3), 203–210.
- Halawi, M.J., Vovos, T.J., Green, C.L., Wellman, S.S., Attarian, D.E., Bolognesi, M.P., 2015. Preoperative predictors of extended hospital length of stay following total knee arthroplasty. *J. Arthroplast.* 30 (3), 361–364.
- Hinkle, D.E., Wiersma, W., Jurs, S.G., 2003. *Applied Statistics for the Behavioral Sciences*. Houghton Mifflin, Boston.
- Holm, B., Bandholm, T., Lunn, T.H., Husted, H., Aalund, P.K., Hansen, T.B., Kehlet, H., 2014. Role of preoperative pain, muscle function, and activity level in discharge readiness after fast-track hip and knee arthroplasty. *Acta Orthop.* 85 (5), 488–492.
- Hoogbeem, T.J., Oosting, E., Vriezolk, J.E., Veenhof, C., Siemonsma, P.C., de Bie, R.A., van den Ende, C.H., van Meeteren, N.L., 2012. Therapeutic validity and effectiveness of preoperative exercise on functional recovery after joint replacement: a systematic review and meta-analysis. *PLoS One* 7 (5), e38031.
- Husted, H., Holm, G., Jacobsen, S., 2008. Predictors of length of stay and patient satisfaction after hip and knee replacement surgery: fast-track experience in 712 patients. *Acta Orthop.* 79 (2), 168–173.
- Husted, H., Lunn, T.H., Troelsen, A., Gaarn-Larsen, L., Kristensen, B.B., Kehlet, H., 2011. Why still in hospital after fast-track hip and knee arthroplasty? *Acta Orthop.* 82 (6), 679–684.
- Jenkins, P.J., Clement, N.D., Hamilton, D.F., Gaston, P., Patton, J.T., Howie, C.R., 2013. Predicting the cost-effectiveness of total hip and knee replacement: a health economic

- analysis. *The bone & joint journal* 95 (1), 115–121.
- Kehlet, H., 2013. Fast-track hip and knee arthroplasty. *Lancet* 381 (9878), 1600–1602.
- Lisi, C., Caspani, P., Bruggi, M., Carlisi, E., Scole, D., Benazzo, F., Dalla Toffola, E., 2017. Early rehabilitation after elective total knee arthroplasty. *Acta Biomed. Atenei Parmensis* 88 (4 -S), 56–61.
- Lovald, S.T., Ong, K.L., Malkani, A.L., Lau, E.C., Schmier, J.K., Kurtz, S.M., Manley, M.T., 2014. Complications, mortality, and costs for outpatient and short-stay total knee arthroplasty patients in comparison to standard-stay patients. *J. Arthroplast.* 29 (3), 510–515.
- Malviya, A., Martin, K., Harper, I., Muller, S.D., Emmerson, K.P., Partington, P.F., Reed, M.R., 2011. Enhanced recovery program for hip and knee replacement reduces death rate. *Acta Orthop.* 82 (5), 577–581.
- Pelt, C.E., Anderson, M.B., Pendleton, R., Foulks, M., Peters, C.L., Gililand, J.M., 2017. Improving value in primary total joint arthroplasty care pathways: changes in inpatient physical therapy staffing. *Arthroplasty today* 3 (1), 45–49.
- Podsiadlo, D., Richardson, S., 1991. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J. Am. Geriatr. Soc.* 39 (2), 142–148.
- Shan, L., Shan, B., Suzuki, A., Nouh, F., Saxena, A., 2015. Intermediate and long-term quality of life after total knee replacement: a systematic review and meta-analysis. *J Bone Joint Surg Am* 97 (2), 156–168.
- Shields, R.K., Enloe, L.J., Evans, R.E., Smith, K.B., Steckel, S.D., 1995. Reliability, validity, and responsiveness of functional tests in patients with total joint replacement. *Phys. Ther.* 75 (3), 169–176.
- Specht, K., Agerskov, H., Kjaersgaard-Andersen, P., Jester, R., Pedersen, B.D., 2018. Patients' experiences during the first 12 weeks after discharge in fast-track hip and knee arthroplasty - a qualitative study. *Int. J. Orthop. Trauma Nurs.* 31, 13–19.
- Specht, K., Kjaersgaard-Andersen, P., Kehlet, H., Pedersen, B.D., 2015. Nursing in fast-track total hip and knee arthroplasty: a retrospective study. *International journal of orthopaedic and trauma nursing* 19 (3), 121–130.
- Szots, K., Pedersen, P.U., Hordam, B., Thomsen, T., Konradsen, H., 2015. Physical health problems experienced in the early postoperative recovery period following total knee replacement. *Int. J. Orthop. Trauma Nurs.* 19 (1), 36–44.
- Toh, H.J., Lim, Z.Y., Yap, P., Tang, T., 2017. Factors associated with prolonged length of stay in older patients. *Singap. Med. J.* 58 (3), 134–138.
- Uesugi, K., Kitano, N., Kikuchi, T., Sekiguchi, M., Konno, S., 2014. Comparison of peripheral nerve block with periarticular injection analgesia after total knee arthroplasty: a randomized, controlled study. *Knee* 21 (4), 848–852.
- van der Sluis, G., Goldbohm, R.A., Bimmel, R., Garre, F.G., Elings, J., Hoogeboom, T.J., van Meeteren, N.L., 2015. What augmented physical activity and empowerment can bring to patients receiving total knee replacement: content, implementation, and comparative effectiveness of a new function-tailored care pathway in a routine care setting. *Biomed Res Int* 745864.
- Wright, A.A., Cook, C.E., Flynn, T.W., Baxter, G.D., Abbott, J.H., 2011. Predictors of response to physical therapy intervention in patients with primary hip osteoarthritis. *Phys. Ther.* 91 (4), 510–524.
- Wynter-Blyth, V., Moorthy, K., 2017. Prehabilitation: preparing patients for surgery. *BMJ (Clinical research ed.)* 358, j3702.
- Yoon, R.S., Nellans, K.W., Geller, J.A., Kim, A.D., Jacobs, M.R., Macaulay, W., 2010. Patient education before hip or knee arthroplasty lowers length of stay. *J. Arthroplast.* 25 (4), 547–551.
- Zhu, S., Qian, W., Jiang, C., Ye, C., Chen, X., 2017. Enhanced recovery after surgery for hip and knee arthroplasty: a systematic review and meta-analysis. *Postgrad. Med.* 93 (1106), 736–742.