Fast-track revision knee arthroplasty. A multicenter cohort study on 1439 elective aseptic major component revision knee arthroplasties

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Article info
Article history:
Received 1 March 2021
Revised 21 June 2021
Accepted 5 September 2021

Keywords:
Revision knee arthroplasty
Knee replacement
Fast-track
Rapid recovery
Safety
Readmissions

Abstract
Background: Limited data exist on fast-track protocols in relation to revision knee arthroplasty. Hence, the aim of this study was to report length of stay (LOS), risk of LOS > 5 days and readmission ≤ 90 days after revision knee arthroplasty in centers with a well-established fast-track protocol in both primary and revision surgery.

Methods: An observational cohort study from the Centre for Fast-track Hip and Knee Replacement and the Danish Knee Arthroplasty Register. We included elective aseptic major component revision knee arthroplasties consecutively from 6 dedicated fast-track centers from 2010 to 2018.

Results: 1439 revision knee arthroplasties were analyzed, including 900 total revisions, 171 large partial revisions (revision of either femoral or tibia component) and 368 revisions of unicompartmental knee arthroplasty (UKA) to total knee arthroplasty (TKA). Mean age was 65 years (SD 10.9) and 66% were females. Mean LOS was 3.7 days (SD 3.9) in the study period, but decreased to 2.4 days (SD 1.3) in 2018. Risk factors for LOS > 5 days was previous revision, use of walking aid, BMI > 35, ages < 50, 70–79 and ≥ 80 years, whereas revision of UKA to TKA and large partial revision were negatively associated. The 90-day readmission and mortality risk was 9.1% and 0.5%. Cardiac disease and use of walking aid were associated with increased risk of readmission ≤ 90 days.

Conclusion: Elective aseptic major component revision knee arthroplasty using similar fast-track protocols as in primary TKA is safe with short and decreasing LOS.

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Abbreviations: SD, Standard deviation; LOS, Length of hospital stay; DNPR, Danish National Patient Registry; DKR, Danish Knee Arthroplasty Register; LIA, local infiltration analgesia.
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https://doi.org/10.1016/j.knee.2021.09.001
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1. Introduction

Favorable outcomes with low postoperative morbidity and short length of hospital stay (LOS) have been reported after fast-track primary total knee arthroplasty (TKA) during the last decades. Furthermore, risk factors and role of patient characteristics in fast-track primary TKA have been investigated thoroughly [1,2]. However, limited data exist on fast-track / enhanced recovery protocols in relation to revision knee procedures with a more extensive surgical trauma. Since the number of revision knee arthroplasty procedures is increasing and expected to increase substantially within the next decades [3], it is relevant to investigate whether these patients can benefit from fast-track protocols in the same way as after primary TKA.

A recent single-center case-control study on 40 aseptic full-component revision TKA’s versus 40 primary TKA’s [4], showed the feasibility of a fast-track approach in revision TKA with short LOS (1.4 days), low risk of readmissions and similar early functional outcome compared to primary TKA [4]. Another recent study on fast-fast-track revision knee arthroplasty reported on 142 mixed types of septic/aseptic knee revision procedures with LOS of 5 days after the aseptic procedures [5]. However, large scale data on patient safety and the role of patient characteristics in fast-track revision knee arthroplasty is lacking.

Hence, the aim of this study was to report LOS, risk of LOS > 5 days and readmission ≤ 90 days after elective aseptic major component revision knee arthroplasty in centers with a well-established fast-track protocol in both primary and revision surgery.

2. Methods

2.1. Study design

This is an observational cohort study on patients from the Centre for Fast-track Hip and Knee Replacement (www.fthk.dk). The STROBE guideline for reporting of an observational study was followed [6]. The revision procedures reported on in this study was also a part of the study cohort of a study specifically analyzing the risk of venous thromboembolism after both revision hip and knee arthroplasty procedures [7].

2.2. Setting

We included a consecutive cohort of unselected and elective fast-track aseptic major component revision knee arthroplasties from 6 dedicated fast-track centers from January 11, 2010, to June 29, 2018. The dedicated fast-track centers agreed to use similar fast-track protocols in elective revision procedures comparable to the perioperative care process for primary TKA [8].

The fast-track protocol includes planned use of multimodal opioid-sparing analgesia, intended early mobilization (<6 hours postoperatively), and discharge to own home based on functional discharge criteria (independent in personal care, able to walk with crutches, able to get in and out of bed and into and up from a chair, and sufficient oral pain treatment) [9]. Preoperative high-dose glucocorticoid (125 mg methylprednisolone/25 mg dexamethasone) [10] was used as a standard of care in 4 centers during the whole study period, in 1 center only from 2018 and not at all in 1 center. Intraoperative high volume local infiltration analgesia (LIA) with 300 mg ropivacaine (0.2%) and epinephrine (10 mg/mL) in a total volume of 150 mL was used in all centers [11]. Furthermore, 1 gram of tranexamic acid was administered intravenously during surgery in all centers. There was no mutual guideline regarding type of anesthesia, use of tourniquet and use of surgical drain - this was based on surgeon and center preferences. Postoperative thromboprophylaxis was administered 6 to 8 hours after surgery and only used during primary admission if LOS ≤ 5 days in all centers during the whole study period. If LOS > 5 days national recommendations [12] were followed and thromboprophylaxis were used up to 14 days in the period from 2010 to 2016 and for 6 to 10 days from 2016 to 2018 [7].

2.3. Data sources

All elective aseptic major component revision knee arthroplasty procedures were identified from the Danish Knee Arthroplasty Register (DKR) [13]. Furthermore, information on type of revision, indications, previous revisions, duration of surgery, use of tourniquet and drainage was obtained from DKR.

Data on preoperative comorbidity and patient characteristics were prospectively collected from patients within 1 month before surgery using self-completed questionnaires with staff available for assistance. Validation of the consistency of the preoperative patient questionnaire has been performed previously using matched patient medical records [14].

Supplementary data on pharmacologically treated diabetes and psychiatric disorders was obtained from The Danish National Health Service Prescription Database.

Data on LOS, readmissions and mortality within 90 days postoperatively were obtained from the Danish National Patient Registry (DNPR) with > 99% completeness of follow-up [15]. Data on specific complications was based on review of discharge
summaries or health-records in case of LOS > 5 days and 90-day readmission or mortality. Review of health-records was done by YC, PBP and MLL.

2.4. Outcomes

The primary objective was to investigate LOS, risk of complications within 90 days postoperatively by analyzing causes of prolonged LOS (>5 days) and readmissions. A LOS > 5 days was considered prolonged based on median LOS of 5 days found by Joseph et al in the largest cohort of fast-track aseptic revision knee arthroplasties reported on so far [5]. We obtained information on LOS (number of postoperative overnight stays, including transfers to other departments and hospitals) and readmissions within 90 days postoperatively (requiring 1 overnight stay and being potentially related to index procedure). Additionally, we obtained information on 90-day incidence of complications not requiring overnight stay.

Figure 1. Study cohort. Flow-chart showing in- and exclusions.
2.5. Patients and surgical procedures

Data on 3118 revision knee arthroplasties performed in the 6 centers from January 2010 to June 2018 was acquired. We excluded all non-elective revisions, including revisions due to infection and fracture by indications registered in the DKR. Revisions procedures on aseptic indications that turned out to be infected (positive intraoperative cultures from tissue biopsies and subsequent prolonged iv antibiotics treatment) were also excluded. Furthermore, we excluded minor revisions, including isolated polyethylene liner exchange, revision of mini-implants (hem-cap/uni-cap revisions) and secondary insertion or exchange of a patella button. Finally, cases with mis-matching operation date > 30 days between DKR and DNPR were excluded. Hence, a total of 1439 elective aseptic major component revision knee arthroplasties performed in 1313 patients were available for analysis. (Figure 1) The mean age of the patients was 65 years (Standard Deviation (SD) 10.9) and 66% were females.

The revision procedures were divided into total component revisions (n = 900), large partial revisions (revision of either femoral or tibia component) (n = 171), and revision of unicompartmental knee arthroplasties (UKA) to total knee arthroplasties (TKA) (n = 368).

Indications for revision surgery were aseptic loosening (42.3%, n = 608), instability (29.6%, 426), pain without loosening (21.4%, n = 308), progression of arthrosis (10.5%, n = 151) polyethylene wear (7.8%, n = 112), and other (11.1%, n = 161). As more than one indication can be registered in DKR, percentages add up to more than 100%. The indication “other” was scrutinized for potential acute indications (e.g. fracture) and excluded.

2.6. Statistics

As all eligible procedures were included no pre-study power calculation was performed. Analysis of potential risk factors associated with prolonged LOS > 5 days and readmission were performed using a multivariable logistic regression model. Analysis of missing variables was performed and indicated all missing data was missing at random. Consequently, multiple imputations were used to account for missing values by constructing 5 different imputed datasets and using the averages of these in final analysis. Percentages of missing values are presented in Table 1. The variables included in the risk factor analysis were chosen based on previous studies on preoperative patient characteristics and postoperative morbidity of fast-track primary TKA [1] and a nationwide study on early morbidity after aseptic revision knee arthroplasty [16]. Continuous variables are given as mean (SD) or median (interquartile range (IQR)) as appropriate. Categorical data are presented as n (%). A two-tailed P-value of < 0.05 was considered to be statistically significant.

Analysis was done using SPSS version 24 (2016; Armonk, NY: IBM Corp.).

Table 1
Patient and surgical characteristics.

<table>
<thead>
<tr>
<th></th>
<th>All procedures</th>
<th>Total revisions</th>
<th>Large partial revisions</th>
<th>UKA revisions</th>
</tr>
</thead>
<tbody>
<tr>
<td>n (%)</td>
<td>1439 (100)</td>
<td>900 (62.5)</td>
<td>171 (11.9)</td>
<td>368 (25.6)</td>
</tr>
<tr>
<td>Mean age, years (SD)</td>
<td>65.2 (10.9)</td>
<td>65.6 (10.9)</td>
<td>64.9 (10.5)</td>
<td>64.5 (11.0)</td>
</tr>
<tr>
<td>Female sex</td>
<td>950 (66.0)</td>
<td>597 (66.3)</td>
<td>117 (68.4)</td>
<td>236 (64.1)</td>
</tr>
<tr>
<td>Patient characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI ≥ 35</td>
<td>233 (16.2)</td>
<td>154 (17.1)</td>
<td>24 (14.0)</td>
<td>55 (14.9)</td>
</tr>
<tr>
<td>Missing 35 (2.4%)</td>
<td>390 (27.1)</td>
<td>267 (29.7)</td>
<td>44 (25.7)</td>
<td>79 (21.5)</td>
</tr>
<tr>
<td>Use of Walking aid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing 106 (7.4%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Insulin dependent diabetes</td>
<td>41 (2.8)</td>
<td>28 (3.1)</td>
<td>4 (2.3)</td>
<td>9 (2.4)</td>
</tr>
<tr>
<td>*Non-insulin dependent diabetes</td>
<td>132 (9.2)</td>
<td>87 (9.7)</td>
<td>11 (6.4)</td>
<td>34 (9.2)</td>
</tr>
<tr>
<td>Cardiac disease</td>
<td>222 (15.4)</td>
<td>135 (15.0)</td>
<td>27 (15.8)</td>
<td>60 (16.3)</td>
</tr>
<tr>
<td>Missing 20 (1.4%)</td>
<td>141 (9.8)</td>
<td>74 (8.2)</td>
<td>26 (15.2)</td>
<td>41 (11.1)</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing 19 (1.3%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Pharmacological treated psychiatric disorder</td>
<td>276 (19.2)</td>
<td>157 (17.4)</td>
<td>40 (23.4)</td>
<td>79 (21.5)</td>
</tr>
<tr>
<td>Preoperative Hgb ≤ 13 g/dl</td>
<td>327 (22.7)</td>
<td>229 (25.4)</td>
<td>41 (24.0)</td>
<td>57 (15.4)</td>
</tr>
<tr>
<td>Missing 126 (8.8%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgical characteristics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean duration of surgery, min. (SD)</td>
<td>111 (37)</td>
<td>122 (37)</td>
<td>97 (25)</td>
<td>89 (28)</td>
</tr>
<tr>
<td>Previously revised</td>
<td>315 (21.9)</td>
<td>202 (22.4)</td>
<td>72 (42.1)</td>
<td>41 (11.1)</td>
</tr>
<tr>
<td>Missing 20 (1.4%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of anesthesia</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinal/epidural anesthesia</td>
<td>932 (64.8)</td>
<td>589 (65.4)</td>
<td>98 (57.3)</td>
<td>245 (66.6)</td>
</tr>
<tr>
<td>General anesthesia</td>
<td>453 (31.5)</td>
<td>275 (30.6)</td>
<td>64 (37.4)</td>
<td>114 (31.0)</td>
</tr>
<tr>
<td>Combined</td>
<td>54 (3.8)</td>
<td>36 (4.0)</td>
<td>9 (5.3)</td>
<td>9 (2.4)</td>
</tr>
</tbody>
</table>

Data given as n (%) or mean (SD). LOS, postoperative length of stay; IQR, interquartile range; SD, standard deviation; UKA, unicompartmental knee arthroplasty; BMI, body mass index, Hgb, haemoglobin.
3. Results

Overall, mean LOS was 3.7 (SD 3.9) and the median LOS was 3 days (interquartile range (IQR) 2–4), but LOS was decreasing during the study period to a mean LOS of 2.4 days (SD 1.3) and median LOS of 2 days (IQR 1–3) in 2018 (Figure 2A). Overall readmission rate was 9.1% and mortality was 0.5% ≤ 90 days postoperatively. Results from the surgical subgroups are presented in Table 2.

In 12.9% of cases, LOS > 5 days and considered prolonged. The risk of LOS > 5 days decreased during the study period and was 1.1% in 2018 (Figure 2B). The fraction of patients with LOS > 5 days was higher after total revisions (16.9%) compared with large partial revisions (9.4%) and UKA to TKA revisions (4.9%). Risk factors associated with LOS > 5 are presented in Table 3.

The most frequent complications causing LOS > 5 days were pain (1.4% of all cases, n = 20), postoperative anemia requiring blood transfusion (1.2%, n = 17), mobilization problems (1.1%, n = 16) and other surgical complications (1.3%, n = 19).

Figure 2. A, B and C: Time-trends and outcomes. Changes in mean LOS (A), risk of LOS > 5 days (B) and risk of readmission ≤ 90 days (C) during the study period from 2010 to 2018.
including fracture (0.4%, n = 6), nerve palsy (0.3%, n = 5), ligament rupture (0.3%, n = 4), dislocation (0.2%, n = 3), and artery lesion (0.1%, n = 1). (Figure 3) In 58 cases no complication was reported as reason for prolonged LOS > 5 days.

The most frequent complications causing readmissions within 90 days postoperatively were related to surgical site infection (2.1% of all cases, n = 31), however only 1.1% (n = 16) were treated with second revision surgery and whether the remaining 1.0% (n = 15) were actually deep periprosthetic infections is uncertain. Cardiac (0.8%, n = 12) and gastrointestinal complications (0.8%, n = 11) were the most frequent medically related complications causing readmission. In 7 (0.5%) cases no information on cause of readmission was available. (Figure 4)

The risk of readmission was fluctuating during the study period, but with a decreasing trend (Figure 2C). Risk factors for readmission are presented in Table 4.

Seven (0.5%) patients died postoperatively at 22, 24, 30, 41, 42 and 76 days postoperatively. None of the deaths happened during primary admission or readmission and detailed data on cause of death were not available.

4. Discussion

The most important finding of this study is that elective aseptic major component revision knee arthroplasty using a fast-track / enhanced recovery protocol is safe. Our study is the first multicenter study on fast-track revision knee arthroplasty procedures from dedicated fast-track centers with similar fast-track protocol in both primary and revision knee arthroplasties.

Previous data on fast-track revision knee arthroplasty is limited. To our knowledge, only 4 specific studies on this subject exist and they all report on smaller single-center cohorts (n = 30, 40, 67 and 142) [4,5,17,18]. Hence, the present study is the
first multicenter study specifically reporting prospectively collected data on a consecutive cohort of revision knee arthroplasties performed in a well-established fast-track setting.

In 2011 Husted et al. reported the feasibility of performing aseptic major component revision knee arthroplasty using the same fast-track algorithm as in primary TKA [17]. This fast-track protocol included a multimodal, orally administered opioid-sparing analgesia, early mobilization on the day of surgery, functional discharge criteria and discharge to the patient’s own home. The same cornerstones of the fast-track protocol were applied in all 6 centers of our study.

Recently, Costales et al. also reported the feasibility of fast-track major component revision knee arthroplasty achieving a mean LOS of 1.4 days, low complication risk and similar Knee Society Scores in 40 patients compared to matched primary TKA patients [4]. Hence, fast-track revision knee arthroplasty has been shown to be feasible in a single center set-up using a strict protocol [4,17] and the results from our multicenter study confirm the safety of fast-track revision knee arthroplasty in general.

The mean LOS of 3.7 days in our study (the whole study period) was lower than 5 days reported from Joseph et al [5], but higher compared to 1–2 days achieved in the studies by Costales et al. and Husted et al. [4,17]. A longer LOS is expected when reporting data from a much larger consecutive multicenter cohort. However, LOS decreased remarkably during the study period to a mean of 2.4 days in 2018 and risk of LOS > 5 days decreased from 23% in 2010 to 1.1% in 2018 - potentially as a result of the constantly evolving and dynamic fast-track concept. For comparison, nationwide data from Denmark [16] in a period from 2009-2011 showed a mean LOS was 4.6 days (median 4 days) in a cohort of aseptic knee revision including polyethylene exchange procedures, which also confirm the benefits and evolvement of the fast-track concept in revision knee surgery through the last decade.

The risk of readmission was 5.6% within 30 days and 9.1% within 90 days, which is at the same level as 8% reported after fast-track primary TKA in the same period [8]. This is encouraging and confirm that patient safety within the first
90 postoperative days are similar to primary TKA despite the more extensive surgical trauma. As in primary TKA, our data confirms that a short LOS after revision knee arthroplasty does not result in increased risk of readmission. In fact, risk of readmission did not increase during the study period while LOS was decreasing (Figure 2).

The higher risk of prolonged LOS > 5 days after total revision procedures (17%) compared to large partial revisions (9%) and UKA to TKA revisions (5%) confirm that surgical trauma does influence the risk of in-hospital complications and LOS. This was also confirmed in the multivariate risk factor analysis showing a less extensive large partial revision and UKA to TKA revision were associated with decreased risk of LOS > 5 days. In contrast, the risk of readmission within 90 days was at the same level between surgical subgroups.

When analyzing potential preoperative risk-factors for LOS > 5 days and readmissions we found several surprising differences compared to in primary fast-track TKA and total hip arthroplasty (THA). Thus, preoperative anemia has been shown to be a significant risk factor for increased postoperative morbidity in primary fast-track TKA/THA [19], but was not associated with risk of LOS > 5 days or readmission in our study. Some of this may be explained by our study focusing on knee revisions only, as THA patients is associated with increased risk of blood transfusions and are often older than TKA patients [19,20]. Psychiatric disease and insulin dependent diabetes are also known risk factors for postoperative morbidity in fast-track primary TKA/THA, but not in our study on revision procedures. In contrast, use of walking aids, body mass index (BMI) > 35, increasing age were associated with LOS > 5 days just as in primary THA and TKA [1]. Furthermore, that cardiac disease and use of walking aids were associated with 90-days readmissions is consistent with findings from primary procedures [1].

The observational nature is a limitation of this study. Other limitations is the lack of information on cause of death in the 0.5% of patients dying within 90 days postoperatively and the unavailable information on cause of readmission in 0.5% of cases. Furthermore, there was also a low proportion of missing data on preoperative patient characteristics, but this was accounted for using multiple imputations.

However, our study is the first study from a large unselected consecutive cohort reporting data on fast-track revision knee arthroplasties from a multicenter collaboration with a well-established fast-track set-up in both primary and revision knee arthroplasty [8]. We provide detailed information on complications leading to prolonged LOS or readmissions after revision knee arthroplasty and risk-factor analysis based prospectively collected patient characteristics with a minimal recall bias. Another strength of this study is the follow-up through a high-quality nationwide register [15]. Additional strengths are not relying on diagnostic codes alone, but using review of discharge notes and patient records for specific causes of morbidity ensures > 99% follow-up on readmissions [15] thereby eliminating the dependency on the questionable reliability of a discharge diagnosis within the DNPR [21–23].

5. Conclusion

In conclusion, elective aseptic major component revision knee arthroplasty using the same fast-track protocol as in primary TKA is safe and achieving a mean LOS of 2.4 days. Independent risk factors for LOS > 5 days were ≥ 1 previous revision,
use of walking aid, BMI > 35, age < 50 years and age ≥ 70, whereas cardiac disease and use of walking aid were associated with increased risk of readmission.

**Authors’ contribution**

MLL, PBP, CJ and HK wrote study protocol and analysis plan. MLL, PBP and YC undertook data gathering. MLL and CJ performed analysis. MLL wrote first draft of the manuscript and all authors and collaborators revised the draft and approved final manuscript.

**Ethical approval**

According to Danish law no approval from the regional ethics committee was needed as the study was non-interventional. The Centre for Fast-Track Hip and Knee Replacement Database is registered as an ongoing study registry on clinicaltrials.gov (NCT01515670).

**Informed consent**

Permission to obtain and store data without informed consent was given from the Danish Patient Safety Authority (3–3013-56/2/EMJO) and the Danish Data Protection Agency (RH-2014-132).

**Funding**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Acknowledgements**

The patients in this study underwent revision knee surgery at the centers participating in the Centre for Fast-track Hip and Knee Replacement Collaboration. The surgeons in the collaborating group listed below reviewed and approved the final manuscript.

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