Postoperative pain as a risk factor for stiff knee following total knee arthroplasty and excellent patient-reported outcomes after manipulation under anesthesia

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Background and purpose — Manipulation under anesthesia (MUA) is the first-choice treatment for stiffness following total knee arthroplasty (TKA) unresponsive to pain management and physiotherapy. Some of the predisposing factors and patient-reported outcome measures (PROMs) following MUA remain poorly studied. We retrospectively investigated the etiological risk factors and the outcomes of MUA.

Patients and methods — 391 TKA patients from a randomized trial comparing the use of a tourniquet and anesthesia (spinal or general) were analyzed, and patients needing MUA were identified (MUA group). We evaluated in-hospital opioid consumption, Oxford Knee Score (OKS), range of motion (ROM), and pain assessed by the Brief Pain Inventory-short form with a 1-year follow-up.

Results — 39 (10%) MUA patients were identified. The MUA patients were younger (60 years vs. 64 years, difference –4, 95% CI –6 to –1) and had higher postoperative oxycodone consumption (66 mg vs. 51 mg, median difference 11, CI 1–22) than the no-MUA patients. The proportion of MUA patients who contacted the emergency department within 3 months because of pain was larger than that of non-MUA patients (41% vs. 12%, OR 5, CI 3–10). At the 1-year follow-up, the ROM was improved by 39° following MUA, but the total ROM was worse in the MUA group (115° vs. 124°, p < 0.001). No difference was found in the OKS between the MUA and no-MUA patients.

Interpretation — Higher postoperative pain seems to predict MUA risk. MUA performed 3 months postoperatively offers substantial ROM improvement and comparable PROMs to no-MUA patients 1 year after TKA.

Some patients will experience painful and functionally impaired stiff knees following total knee arthroplasty (TKA) (1). Several reasons for post-TKA stiffness have been proposed, with a low preoperative range of motion (ROM) described as the most important (2,3). Young age, prior surgeries on the target knee, lack of compliance, poor pain management, genetic factors, female sex, obesity, and tobacco smoking are also previously described risk factors (2-4). Additionally, component malalignment and oversizing have been described as causes of decreased function and ROM (2,5). The incidence of post-TKA stiffness has varied in recent studies, ranging from 0.5 to 16.6% (4,6-9).

The primary treatment for a stiff knee unresponsive to physiotherapy is manipulation under anesthesia (MUA) (2). MUA is a relatively safe procedure with a complication rate of < 1% (2,10,11). The optimal time point for MUA is a matter of debate. Several optimal time points for MUA, from 2 weeks to 4 months, have been suggested to achieve satisfactory results. However, MUA within the first 12 postoperative weeks is considered the most beneficial timing (2,4). The data regarding patient-reported outcome measures (PROMs), prolonged pain, and patient satisfaction after MUA is limited (2).

We aimed to identify the predisposing factors for postoperative stiff knee requiring MUA and MUA outcomes in a prospective patient cohort with 1 year of follow-up.

Patients and methods

Patients
We conducted a retrospective comparative analyses with regard to MUA for 391 patients who had undergone fast-track
TKA in a randomized trial comparing the use of a tourniquet and two anesthesia methods (spinal or general) with a 1-year follow-up (12,13).

The original study was conducted at a single tertiary university hospital between October 2016 and December 2019. Patients aged 18–75 years with Kellgren–Lawrence grade 3–4 knee osteoarthritis, BMI ≤ 40, and ASA physical status class I–III who were eligible for TKA were included in the original study. Exclusion criteria were prior major surgery on the same knee, severe malalignment in mechanical axis (MA) radiograph (> 15°), severe extension (> 20°) or flexion (< 90°) deficits, and ongoing strong opioid usage.

Methods
We examined patient demographics and medical history, and the preoperative and 3- and 12-month outcome data. The outcome measures included Oxford Knee Score (OKS), OKS minimal important change (MIC) ≥ 6.5 points (14), Brief Pain Inventory short form (BPI-sf) (15), ROM measured using a goniometer, patient satisfaction with TKA assessed using a numerical rating scale (NRS 9–10 defined as satisfied with TKA and 0–8 defined as dissatisfied/other) and Patient Acceptable Symptom State (PASS; OKS ≥ 37 denotes satisfactory outcome with TKA) (16), and 15D health-related quality of life (HRQoL, 15D). We also examined the surgical and tourniquet times, anesthesia method, in-hospital oxycodone consumption, postoperative in-hospital pain with the NRS, length of stay (LOS), complications, and contacts with the emergency unit for any reason. A radiologist who was blinded to the outcomes evaluated the preoperative MA, postoperative tibio-femoral (TF) angle, and component position in terms of the femoral component medial angle (FMA), femoral component flexion angle (FFA), tibial component medial angle (TMA), and posterior tibial slope (PTS) from the preoperative and postoperative radiographs. Post-TKA stiffness and indication for MUA was defined as flexion < 90° 3 months after surgery when infections, obvious malalignments, and component malposition clinically and by evaluating postoperative radiographs. MUA was performed as a closed procedure for all patients under general anesthesia with mask ventilation and a muscle relaxant. With the hip flexed to 90°, gentle and steady force was applied to the knee until audible separation of adhesions no longer occurred. Stability and ROM were investigated before and after MUA. Every patient received intra-articular bupivacaine following MUA. Immediate ambulation was performed with multimodal analgesia. All the MUA patients received a postoperative physiotherapist consultation and were given a home-based knee exercise manual.

Statistics
We divided the patients into 2 groups based on whether they underwent MUA (i.e., MUA and no-MUA). Normally distributed data were expressed as means (SD), non-normally distributed variables as medians (range), and differences for both with 95% confidence intervals (CI). Categorical data were expressed as frequencies and percentages with odds ratios (OR) and CI. To examine the differences in the continuous variables between the groups, we used the independent samples t-test and Mann–Whitney U-test. Fisher and chi-square tests and binary logistic regression were used to analyze the categorical data. We used IBM SPSS Statistics 27 (IBM Corp, Armonk, NY, USA) for all analyses, which were verified by an independent professional biostatistician.

Ethics, funding, and conflict of interest
The original study was approved by HUS Helsinki University Hospital and the Helsinki and Uusimaa District Ethics committee (June 8, 2016, ref: HUS1703/2016) and the Finnish Medicines Agency Fimea (June 8, 2016, ref: HUS1703/2016 and May 20, 2016, ref: KL72/2016). The original study was registered in EudraCT (May 12, 2016, ref: 2016-002035-15).
Table 1. Patient characteristics. Values are count (%) unless otherwise specified

| Characteristic                          | MUA (n = 39) | No MUA (n = 352) | Odds ratio (95% CI) | Mean difference (95% CI) |
|----------------------------------------|--------------|------------------|---------------------|-------------------------|
| Female sex                             | 29 (74)      | 220 (63)         | 1.7 (0.8–3.7)       | 0.6 (0.2–2.2)           |
| BMI, mean (SD)                         | 30 (4)       | 31 (5)           | 0.7 (0.2–1.4)       | 0.2 (0.4–0.0)           |
| ASA score I–III, mean (SD)             | 2.1 (1)      | 2.2 (1)          | 0.2 (0.7–1.1)       | 0.0 (0.7–0.3)           |
| Current smoking                        | 3            | 41               | 0.8 (0.4–3.6)       | 0.3 (0.7–0.1)           |
| Alcohol use, median doses/week (range) | 1 (0–16)     | 1 (0–30)         | 0.9 (0.4–2.3)       | 0 (0–0.5) *             |
| Diabetes mellitus                      | 6            | 58               | 0.5 (0.3–1.1)       | 0.2 (0.0–1.6)           |
| Medication for hypertension            | 16           | 198              | 0.5 (0.3–1.1)       | 0.2 (0.0–1.6)           |
| Sleep apnea (also suspected)           | 1            | 38               | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Antithrombotic medication              | 7            | 73               | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Asthma or COPD                         | 4            | 49               | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Sleep apnea (also suspected)           | 1            | 38               | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Tourniquet in use                     | 23 (59)      | 174 (49)         | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Spinal anesthesia                     | 14 (36)      | 184 (52)         | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| General anesthesia                     | 25 (64)      | 168 (48)         | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Prior surgery to target knee b        | 12 (32)      | 144 (41)         | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Reason for operation                   |              |                  |                     |                        |
| Primary arthrosis                     | 36 (92)      | 329 (94)         | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Rheumatoid/psoriatic arthritis        | 2            | 10               | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |
| Post-traumatic arthrosis              | 1            | 7                | 0.5 (0.1–3.8)       | 0.2 (0.0–1.6)           |

MUA = manipulation under anesthesia; COPD = chronic obstructive pulmonary disease; PE = pulmonary embolism; DVT = deep vein thrombosis.

* Hodges–Lehman estimate for median difference.

b Minor surgery includes debridement or partial meniscectomy of the knee.

Signed informed consent was collected from every patient before participating in the original study (17). The study was funded by Helsinki University Hospital Finnish Government Science Grant, Helsinki University Hospital Grant, the Piävikki and Sakari Sohlberg Foundation, the Finnish Medical Foundation, the Research Foundation for Orthopaedics and Traumatology, and the Finnish Arthroplasty Association. The funders of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The authors declare no conflicts of interest.

Results

The incidence of MUA was 10% (39/391). 5 patients with ROM < 90° (patients with extension deficit between 0° and 20° and knee flexion between 90° and 105°) at 3 months declined MUA. Every MUA patient completed the PROM questionnaires 1 year after TKA, and ROM was measured in 37 of the 39 patients. In the control group, the PROMs were completed by 343–346 of the 352 patients and ROM measured from 338 patients at the 1-year follow-up.

Patients needing MUA were significantly younger than the no-MUA patients (MUA 60 years [SD7] vs. no-MUA 64 years [SD7], mean difference –4, CI –6 to –1). No clinically significant differences were found regarding sex, BMI, alcohol or tobacco use, comorbidities, prior surgery on the target knee, or preoperative OKS, ROM, BPI-sf, and 15D (Tables 1 and 2). Surgical and tourniquet times, oxycodone consumption in the first 24 hours with PCA, postoperative pain at 24 hours, and LOS were similar between the 2 groups (Tables 3 and 4). However, in-hospital oral oxycodone consumption (MUA 25 mg vs. no-MUA 20 mg, median difference 10, CI 0–20), and total postoperative in-hospital oxycodone consumption (MUA 66 mg vs. no-MUA 51 mg, median difference 11, CI 1–22) were significantly higher in the MUA group. The radiological evaluation revealed no differences between the groups in terms of the preoperative MA angle or postoperative TF angle, component sizing, or positioning (Table 5).

At the 3-month follow-up, prior to MUA, the OKS, ROM, and BPI-sf pain scores differed significantly, favoring no-MUA patients (Table 2). The proportion of MUA patients who contacted the emergency department because of pain was larger than that of non-MUA patients (MUA [16/39] vs. no-MUA [43/352], OR 5, CI 3–10). The groups were similar in terms of other complications (Table 6). The average time between index surgery and MUA was 13 weeks (SD 3, range 9–27). Following MUA, the patients were discharged on the day of MUA (34/39) or the first postoperative (5/39) day.

At 12 months, the improvement in OKS and the final OKS were similar. Additionally, no clinically important differences were noted regarding pain assessed using the BPI-sf (Table 2). Moreover, no statistically significant differences were found regarding the proportion of patients reaching OKS MIC (MUA [29/37] vs. no-MUA [29/341], OR 0.5, CI 0.2–1.2) or OKS PASS (MUA [27/38] vs. no-MUA [282/344], OR 0.5, CI 0.3–1.2). However, satisfaction with TKA was significantly greater in the no-MUA group (MUA [30/39] vs. no-MUA [298/337], OR 0.4, CI 0.2–0.99). The ROM was improved by 39° following MUA at the 1-year follow-up. The final ROM at 12 months was < 90° in only 1 patient in the MUA group and 1 patient in the no-MUA group (80° and 85°, respectively; Table 2). None of the MUA patients needed a second MUA, arthroscopic arthrolysis, or revision (Table 6). No complications related to MUA were noted.

Discussion

We found that postoperative pain was associated with stiffness, suggesting an unfavorable biological response to surgery or pain tolerance in this group. Additionally, we found that MUA performed 3 months after TKA is effective with a
In a retrospective study of 1,136 TKA patients by Lavernia et al., multimodal analgesia decreased the MUA incidence from 5% to 2% (18). However, in a recent study by Harmer et al., no relationship between in-hospital postoperative pain and decreased ROM was noted (19). In contrast, our study found that patients needing MUA required more opioids during the in-hospital period and had substantially more pain during the first 12 postoperative weeks than the no-MUA group. These findings implies that postoperative pain is a critical etiological factor in stiffness, even with standardized and up-to-date multimodal pain management.

The different timing, ROM thresholds, and surgeons’ and patients’ perceptions of adequate ROM in clinical practice affect the incidence of MUA (4). The choice to perform MUA for individual patients remains unclear in many retrospective studies, and a lack of consensus regarding the optimal timing and ROM thresholds for MUA exists (4,8,11,20). If a very early time point for MUA is chosen, many patients may receive unnecessary procedures, possibly increasing the complication rate (21). On the other hand, if a very late timepoint is selected, the benefit of MUA may be meager (20). However, a threshold of < 90° flexion at 12 weeks postoperatively can be considered the most usual indication for MUA (2,4,19).

In a recent retrospective study, the incidence of MUA in fast-track TKA was reported to be 2% (22). However, in a post hoc analysis of a randomized study of 476 TKAs comparing cemented and non-cemented cruciate-retaining TKA by Esler et al., a 10% (47/476) incidence of MUA was found when using a threshold of 80° flexion at 12 months.
Regarding the effect of surgeons’ perception to perform MUA, Vun et al. found that the number of surgeons performing MUA varies from 46% routinely performing to 11% never performing it, affecting the overall number of MUAs performed (24). Ultimately, the surgeon usually decides to perform MUA, which may be influenced by the surgeon’s and patient’s perspectives regarding acceptable outcomes, especially during the early recovery period. In addition, the proportion of patients with stiff knees who decline or otherwise do not end up having MUA remains elusive. Anecdotally, the 5 patients in our study with ≤90° ROM at 3 months who declined MUA ended up with ROM 0–90°, 15–105°, 15–100°, 0–120°, and 0–140° at the 12-month follow-up. To our knowledge, the natural course of the stiff knee remains unexplored.

The previous retrospective case series or matched case-cohort studies have focused mainly on MUA incidence concerning predisposing comorbidities while using ROM as a functional outcome. We found only one previous study reporting PROMs following MUA (25). This study, by Dzaja et al., found comparable PROMs between the MUA patients and the patients not requiring MUA. However, the previous data regarding the outcomes of MUA is confounded in multiple ways. These confounders include differences in TKA performance and implant design, a lack of information on postoperative pain management, inconsistent ROM and time thresholds for MUA, and a lack of information regarding the number of patients declining or not offered MUA.

Our study has several limitations. First, our findings present retrospective analyses of the results of a randomized controlled trial that had complications as a secondary outcome. Thus, the results may possibly be underpowered for a definitive conclusion regarding MUA incidence. Second, we could not evaluate the effects of patellar resurfacing (26), component rotational alignment, or the implant’s single radius design on the risk for MUA. Third, the study population was limited to patients aged no more than 75 years without previous major surgery on the target knee, severe flexion or extension deficits, or malalignment, including only patients with ASA I–III and BMI ≤ 40.

This study’s strengths were the prospective data collection with standardized surgery, anesthesia, and perioperative care creating a comparable control group to the MUA group. Additionally, standardized time and ROM thresholds for MUA were used. Neither group of patients had previous use of strong opioids, preventing the confounding effect of opioid use in interpreting the results. The study included up-to-date fast-track rehabilitation protocols with multimodal pain management, ensuring adequate pain management and rehabilitation. Furthermore, only one implant design with patellar resurfacing was used for all patients and implanted by experienced surgeons, further decreasing the risk of confounders. Moreover, we evaluated the effect of preoperative MA and postoperative component positioning on the risk for MUA.

**Conclusions**

According to our results, MUA performed 3 months postoperatively improves ROM and results in comparable PROMs.
1 year after TKA compared with patients without stiffness. Patients at risk of severe postoperative pain should be screened and offered more targeted and enhanced pain management to avoid postoperative stiffness. MUA performed with consistent time, and ROM thresholds, may possibly decrease the future risk of revision because of stiffness. Future pragmatic prospective studies are needed to evaluate the natural course of postoperative stiffness and the incidence of MUA more accurately.

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Acta Orthopaedica

1. Abram S G F, Yusuf B, Alvand A, Sabah S A, Beard D J, Price A J. Manipulation under anesthesia after primary knee arthroplasty is associated with a higher rate of subsequent revision surgery. J Arthroplasty 2020; 35:2640-5.e2. doi: 10.1016/j.arth.2020.04.015.

2. Zachwieja E, Perez J, Hardaker W M, Levine B, Sheth N. Manipulation under anesthesia and stiffness after total knee arthroplasty. JBJS Rev 2018; 6:e2. doi: 10.2106/jbjs.rvw.17.00113.

3. Thompson R, Novikov D, Cizmic Z, Fong J E, Fideler K, Sayeed Z, et al. Arthrofibrosis after total knee arthroplasty: pathophysiology, diagnosis, and management. Orthop Clin North Am 2019; 50: 269-79. doi: 10.1016/j.jocn.2019.02.005.

4. Tibbo M E, Limberg A K, Salib C G, Ahmed A T, Van Wijnen A J, Berry D J, et al. Acquired idiopathic stiffness after total knee arthroplasty. J Bone Joint Surg Am 2019; 101: 1320-30. doi: 10.2106/jbjs.18.01217.

5. Bedard M, Vince K G, Redfern J, Collen S R. Internal rotation of the tibial component is frequent in stiff total knee arthroplasty. Clin Orthop Relat Res 2011; 469: 2346-55. doi: 10.1007/s11999-011-1889-8.

6. Gadinsky N E, Ehrhardt J K, Urband C, Westrich G H. Effect of body mass index on range of motion and manipulation after total knee arthroplasty. J Arthroplasty 2011; 26: 1194-7. doi: 10.1016/j.arth.2010.12.004.

7. Berg U, Bülow E, Sundberg M, Rolfsen O. No increase in readmissions or adverse events after implementation of fast-track program in total hip and knee replacement at 8 Swedish hospitals: an observational before-and-after study of 14,148 total joint replacements 2011–2015. Acta Orthop 2018; 89: 522-7. doi: 10.1080/17453674.2018.1492507.

8. Newman E T, Herschmiller T A, Attarian D E, Vail T P, Bolognesi M P, Wellman S S. Risk factors, outcomes, and timing of manipulation under anesthesia after total knee arthroplasty. J Arthroplasty 2018; 33: 245-9. doi: 10.1016/j.arth.2017.08.002.

9. Thorsteinsson H, Hedström M, Robertson O, Lundin N, W-Dahl A. Manipulation under anesthesia after primary knee arthroplasty in Sweden: incidence, patient characteristics and risk of revision. Acta Orthop 2019; 90: 484-8. doi: 10.1080/17453674.2019.1637177.

10. Namba S, Inacio M. Early and late manipulation improve flexion after total knee arthroplasty. J Arthroplasty 2007; 22: 58-61. doi: 10.1016/j.arth.2007.02.010.

11. Gu A, Michalak A J, Cohen J S, Almeida N D, McMawhorne A S, Sculco P K. Efficacy of manipulation under anesthesia for stiffness following total knee arthroplasty: a systematic review. J Arthroplasty 2018; 33: 1598-605. doi: 10.1016/j.arth.2017.11.054.

12. Palanne R, Rantasalo M, Vakkuri A, Madanat R, Olkkola K T, Lahtinen K, et al. Effects of anaesthesia method and tourniquet use on recovery following total knee arthroplasty: a randomised controlled study. Br J Anaesthesia 2020; 125: 762-72. doi: 10.1016/j.bja.2020.03.056.

13. Rantasalo M, Palanne R, Vakkuri A, Olkkola K T, Madanat R, Skants N. Use of a tourniquet and spinal anesthesia increases satisfactory outcomes after total knee arthroplasty: a randomized study. J Bone Joint Surg Am 2021; 103: 1890-9. doi: 10.2106/jbjs.20.02080.

14. Beard D J, Harris K, Dawson J, Doll H, Murray D W, Carr A J, et al. Meaningful changes for the Oxford hip and knee scores after joint replacement surgery. J Clin Epidemiol 2015; 68: 73-9. doi: 10.1016/j.jclinepi.2014.08.009.

15. Cleeland C S, Gonin R, Hatfield A K, Edmundson J H, Blum R H, Stewart J A, et al. Pain and its treatment in outpatient with metastatic cancer. N Engl J Med 1994; 330: 592-6. doi: 10.1056/nejm199403303300902.

16. Keurentjes J C, Van Tol F R, Fiocco M, So-Osman C, Onstenk R, Koopman-Van Gemert A W M M, et al. Patient acceptable symptom states after total hip or knee replacement at mid-term follow-up: thresholds of the Oxford hip and knee scores. Bone Joint Res 2014; 3: 7-13. doi: 10.1302/2046-3758.3.200141.

17. Rantasalo M T, Palanne R, Juutilainen K, Kairaluoma P, Linko R, Reponen E, et al. Randomised controlled study comparing general and spinal anaesthesia with and without a tourniquet on the outcomes of total knee arthroplasty: study protocol. BMJ Open 2018; 8: e025546. doi: 10.1136/bmjopen-2018-025546.

18. Laverrnia C, Cardona D, Rossi M D, Lee D. Multimodal pain management and arthrofibrosis. J Arthroplasty 2008; 23: 74-9. doi: 10.1016/j.arth.2008.03.012.

19. Harmer J R, Wyles C C, Mara K C, Warner N S, Trousdale R T. Impact of perioperative pain control on knee range of motion and development of arthrofibrosis following primary total knee arthroplasty. J Arthroplasty 2021; 36: 532-6. doi: 10.1016/j.arth.2020.08.037.

20. Pagoti R, O’Brien S, Blaney J, Doran E, Beaverland D. Knee manipulation for reduced flexion after total knee arthroplasty. Is timing critical? J Clin Orthop and Trauma 2018; 9: 295-9. doi: 10.1016/j.jcot.2017.11.017.

21. Fox J L, Poo S. The role of manipulation following total knee replacement. J Bone Joint Surg Am 1981; 63: 357-62. PubMed PMID: 7204431.

22. Husted H, Jorgensen C S, Gromov K, Troelsen A, Kehlet H, Sabale K, et al. Low manipulation prevalence following fast-track total knee arthroplasty. Acta Orthop 2015; 86: 86-91. doi: 10.3109/17453674.2014.964615.

23. Esler C N, Lock K, Harper W M, Gregg P J. Manipulation of total knee replacements: is the flexion gained retained? J Bone Joint Surg Br 1991; 81: 27-9. doi: 10.1302/0301-620x.81b1.8848.

24. Yun S H, Shields D W, Sen A, Shareef S, Sinha S, Campbell A C. A national questionnaire survey on knee manipulation following total knee arthroplasty. J Orthop 2015; 12: 193-6. doi: 10.1016/j.jor.2015.05.016.

25. Dzaja I, Vasarhelyi E M, Lanting B A, Naudie D D, Howard J L, Vun S H, Shields D W, Sen A, Shareef S, Sinha S, Campbell A C. The role of manipulation following total knee replacement. J Bone Joint Surg Am 1981; 63: 357-62. PubMed PMID: 7204431.

26. Crawford D A, Hurst J M, Morris M J, Berend K R. Does patellar resurfacing in primary total knee arthroplasty increase the risk of manipulation? Surg Technol Int 2020; 36: 299-303. PubMed PMID: 32196562.