Risk factors for manipulation under anaesthesia after total knee arthroplasty

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Aims
Postoperative range of movement (ROM) is an important measure of successful and satisfying total knee arthroplasty (TKA). Reduced postoperative ROM may be evident in up to 20% of all TKAs and negatively affects satisfaction. To improve ROM, manipulation under anaesthesia (MUA) may be performed. Historically, a limited ROM preoperatively was used as the key harbinger of the postoperative ROM. However, comorbidities may also be useful in predicting postoperative stiffness. The goal was to assess preoperative comorbidities in patients undergoing TKA relative to incidence of postoperative MUA. The hope is to forecast those who may be at increased risk and determine if MUA is an effective form of treatment.

Methods
Prospectively collected data of TKAs performed at our institution's two hospitals from August 2014 to August 2018 were evaluated for incidence of MUA. Comorbid conditions, risk factors, implant component design and fixation method (cemented vs cementless), and discharge disposition were analyzed. Overall, 3,556 TKAs met the inclusion criteria. Of those, 164 underwent MUA.

Results
Patients with increased age and body mass index (BMI) had decreased likelihood of MUA. For every one-year increase in age, the likelihood of MUA decreased by 4%. Similarly, for every one-unit increase in BMI the likelihood of MUA decreased by 6%. There were no differences in incidence of MUA between component type/design or fixation method. Current or former smokers were more likely to have no MUA. Surprisingly, patients discharged to home health service or skilled nursing facility were approximately 40% and 70% less likely than those discharged home with outpatient therapy to be in the MUA group. MUA was effective, with a mean increased ROM of 32.81° (SD 19.85°; -15° to 90°).

Conclusion
Younger, thinner patients had highest incidence of MUA. Effect of discharge disposition on rate of MUA was an important finding and may influence surgeons' decisions. Interestingly, use of cement and component design (constraint) did not impact incidence of MUA.

Level of Evidence II: Prospective cohort study.

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Introduction
Total knee arthroplasty (TKA) outcomes are closely linked to patient satisfaction. Patients with lower preoperative functional scores undergoing hip and knee surgery have been found to have inferior outcomes and satisfaction.[1,2] In addition to functional scores, preoperative patient expectations have been shown to affect the overall satisfaction and pain scores after arthroplasty.[3] In the postoperative period for TKA, range of movement (ROM) is also of great importance, as it has been proposed that patients need about 70° of knee flexion to ascend stairs and stand from a seated position and up to 90° to descend stairs.[4,5]

While there are surgeon-dependent factors such as proper axial alignment, implant sizing, and soft tissue releases that lead to the success or failure of arthroplasty, there are also patient-specific risk factors that may influence outcomes. An important aspect of the preoperative evaluation is an assessment of the patient's overall bill of health so that the patient's health status may be optimized prior

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to surgery. Comorbid conditions proposed as risk factors for manipulation under anaesthesia (MUA) in TKA include: body mass index (BMI),[6] diabetes, previous knee surgery, pulmonary disease, depression,[7] tobacco smoking, high cholesterol,[8] and younger age. A recent multicentre study by Newman et al[9] showed no increased rate of MUA in patients with higher American Society of Anesthesiologists (ASA) score,[10] BMI, diabetes, or inflammatory arthropathy. Their patients undergoing MUA were more likely to be younger (mean 55.2 vs 65.3 years of age, p < 0.001), be smokers (21.0% vs 7.3%, p < 0.001), and/or possess a history of prior knee surgery.

TKA component design has also been implicated as a potential surgeon-related factor contributing to postoperative ROM. Yoo et al[11] found that there was a difference in the incidence of MUA in their posterior stabilized (PS) knees (0.4%) compared with the cruciate retaining (CR) knees (2.3%). There has been a recent increase in use of cementless implants but the impact of this design on MUA is unclear. Our goal was to use the prospectively collected and abstracted data from our hospitals' Michigan Arthroplasty Registry Collaborative Quality Initiative registry (MARCQI) to assess the impact of preoperative comorbidities, use of cement, implant design, and discharge disposition on the incidence of MUA after TKA.

Risk factors such as common comorbidities, BMI, and smoking were also examined as these remain controversial throughout the literature.[6-9]

Methods

Institutional Review Board approval was granted through our institution. Prospectively collected and specifically abstracted case data from the MARCQI database for our institution's two hospitals and 12 surgeons were used for analysis. All surgeons followed identical institution-wide postoperative pathways that included preoperative patient education, standardized pain regimens, and physiotherapy sessions. All of the included surgeons favoured the use of MUA when a patient's flexion arc was less than 90˚ to 95˚ at six to eight weeks postoperatively.

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All uncomplicated primary TKAs performed between August 2014 and August 2018 were included. Revision procedures or cases with infection in the postoperative period were excluded. A total of 3,556 TKAs (3,556 patients) were included the analysis (Figure 1). All patients were referred for physiotherapy (PT) postoperatively. We try to standardize postoperative therapy protocols to focus on strength, active and gentle passive ROM, and improving gait dynamics. Unfortunately, we were unable to distinguish how many of these patients received PT within our own facility or if they went elsewhere. The indication for a patient to undergo MUA was variable due to the high number of surgeons included in the study, but typically MUA was performed if the patient was unable to reach 90˚ to 95˚ degrees of flexion

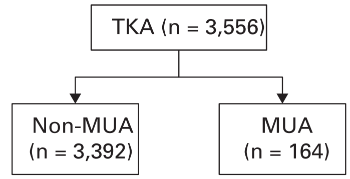

Fig. 1

CONSORT diagram indicating the number of total knee arthroplasties (TKA) that were pulled from the Michigan Arthroplasty Registry Collaborative Quality Initiative registry (MARCQI) database and how many of those received an manipulation under anaesthesia (MUA) versus non-MUA.

by approximately eight weeks. The undertaking of an MUA was solely based on the surgeons' decision. The manipulation was performed in the hospital or in an ambulatory surgery centre (ASC) on an outpatient basis. Under anaesthesia, the knee was then gently brought into deep flexion and terminal extension in order to break any adhesions which were preventing a full ROM. The ROM was carefully recorded at office visits post-procedure in order to monitor the degree of improvement.

Data were collected using the MARCQI database to find all selected parameters including sex, race (Caucasian, black, other, or not specified), age, BMI, preoperative smoking use, ASA score, prior history of deep venous thrombosis (DVT) or pulmonary embolism (PE), pre-existing diabetes mellitus (DM), preoperative anticoagulant use, preoperative narcotic medication, total knee component design (Cruciate Retaining, Posterior Stabilized, Condylar Stabilized, or Total Stabilized), component fixation type (Cemented or Press fit/cementless), and discharge disposition. For some patients, component type and fixation method were not available through the database. Electronic medical records were then reviewed manually for ROM data for the MUA patients at pre-MUA and first, second, and third post-MUA visits. All data were collected and kept on password-protected computers for the purpose of patient confidentiality.

Statistical analysis. An experienced statistician examined categorical variables with chi-squared tests where appropriate (expected frequency of 80% of cells > 5); otherwise, Fisher's exact tests were used. Age and BMI were examined with independent-samples *t*-tests. Odds ratios (ORs) and 95% confidence intervals (CIs) were also calculated. Multivariable logistic regression modelling was conducted to identify potential risk factors for all-cause readmission. Age, sex, and BMI were adjusted for in the regression modelling. Other variables were considered eligible if independent associations with readmission achieved a p-value ≤ 0.20. ORs and 95% CIs were reported to determine the strength of the association between demographic and clinical factors and likelihood of readmission. Logistic regression with MUA as the dependent variable was used for the OR and 95% CI for age, BMI, smoking history, and race. Wald CI was used for all the other variables. Analysis of variance (ANOVA) and Tukey's post hoc tests were run for the analysis of post-MUA ROM improvements. Statistical significance was defined as p ≤ 0.05. All analyses were performed with SPSS, v. 23.0 (IBM, Armonk, New York, USA).

Table I. Comparison of patient and clinical factors between MUA and non-MUA groups.

Variable	Overall		No MUA		MUA		Initial statistical test (p-value)	Post hoc p-value
	Total, n		**Total, n**		**Total, n**			
Mean age, yrs (SD)	3,556	67.1 (9.2)	3,392	67.2 (9.2)	164	64.1 (8.7)	< 0.001	N/A
Mean BMI (SD)	3,556	32.6 (6.5)	3,392	32.7 (6.5)	164	38 (5.5)	< 0.001	N/A
Mean preoperative ASA score (SD)	3,556	2.5 (5)	3,392	2.5 (5)	164	2.4 (5)	< 0.001	N/A
Sex, n (%)	3556		3,392		164		0.128	N/A
Male		1,151 (32)		1,089 (32)		62 (38)		
Female		2,405 (68)		2,303 (68)		102 (62)		
Component type, n (%)	2,878		2,748		130		0.905	N/A
Posterior stabilized		808 (28)		775 (28)		33 (25)		
Cruciate retaining		1,874 (65)		1,786 (65)		88 (68)		
Total stabilized		17 (01)		16 (1)		1 (1)		
Condylar stabilized		179 (06)		171 (6)		8 (6)		
Fixation type	2,916		2,777		139		0.090	N/A
Press fit cementless		823 (28)		775 (28)		48 (35)		
Cemented		2,093 (72)		2,002 (72)		91 (65)		
Preoperative ASA score, n (%)	3,556		3,392		164		0.002*	N/A
1		48 (01)		44 (1)		4 (2)		0.357
2		1,625 (46)		1,529 (45)		96 (59)		0.001
3		1,867 (53)		1,803 (53)		64 (39)		0
4		16 (0)		16 (0)		0 (0)		0.938
Preoperative ASA, n (%)	3,556		3,392		164		< 0.001*	N/A
1.0 to 2.0		1,673 (47)		1,573 (46)		100 (61)		
3.0 to 4.0		1,883 (53)		1,819 (54)		64 (39)		
Race, n (%)	3,556		3,392		164		0.261	N/A
Caucasian		2,336 (66)		2,238 (66)		98 (6)		
Black		928 (26)		875 (26)		53 (32)		
Other		11 (0)		11 (0)		0 (0)		
Unknown		281 (08)		268 (8)		13 (8)		
Mean preoperative BMI, n (%)	3,556		3,392		164		0.010*	N/A
Normal		375 (11)		351 (1)		24 (15)		
Overweight (25 kg/m^2 to 29 kg/m^2)		960 (27)		905 (27)		55 (34)		
Obese (30 kg/m^2 to 34 kg/m^2)		1081 (3)		1,031 (3)		50 (3)		
Severely obese (35 kg/m^2 to 39 kg/m^2)		672 (19)		647 (19)		25 (15)		
Morbidly obese (<40 kg/m^2)		468 (13)		458 (14)		10 (6)		
Preoperative smoking status, n (%)	3,556		3,392		164		0.046	N/A
Never		1,884 (53)		1,783 (53)		101 (62)		
Previous		1,388 (39)		1,339 (39)		49 (3)		
Current		284 (08)		270 (8)		14 (9)		
Preoperative alcohol consumption, n (%)	3,556		3,392		164		0.512	N/A
No		1,324 (37)		1,262 (37)		62 (38)		
Yes (≤ one drink/wk)		1,393 (39)		1,326 (39)		67 (41)		
Yes (two to seven drinks/wk)		568 (16)		539 (16)		29 (18)		
Yes (≥ eight drinks/wk)		210 (06)		205 (6)		5 (3)		
Yes (amount unknown)		39 (01)		38 (1)		1 (1)		
Unknown		22 (01)		22 (1)		0 (0)		
Preoperative alcohol consumption, n (%)	3,534		3,370		164		0.927	N/A
No		1,324 (37)		1,262 (37)		62 (38)		
Yes (any amount)		2,210 (63)		2,108 (63)		102 (62)		
Preoperative bleeding disorder, n (%)	3,556		3,392		164		1.000	N/A
No		3,521 (99)		3,358 (99)		163 (99)		
Yes		35 (01)		34 (1)		1 (1)		
Preoperative history of DVT/PE, n (%)	3,556		3,392		164		0.615	N/A
No		3,235 (91)		3,084 (91)		151 (92)		
Yes		321 (09)		308 (9)		13 (8)		
Preoperative diabetes mellitus, n (%)	3,556		3,392		164		0.351	N/A
No		2,745 (77)		2,616 (77)		129 (79)		
Yes (Type 1)		98 (03)		97 (3)		1 (1)		

Continued

Table I. Continued

Variable	Overall		No MUA		MUA		Initial statistical test (p-value)	Post hoc p-value
Yes (Type 2)		707 (2)		673 (2)		34 (21)		
Yes (type unknown)		6 (0)		6 (0)		0 (0)		
Preoperative diabetes mellitus, n (%)	3,556		3,392		164		0.647	N/A
No		2,745 (77)		2,616 (77)		129 (79)		
Yes (Type 1 or 2)		811 (23)		776 (23)		35 (21)		
Preoperative anticoagulation medication, n (%)	3,501		3,341		160		0.399	N/A
No		3,294 (94)		3,141 (94)		153 (96)		
Yes		207 (06)		200 (6)		7 (4)		
Preoperative narcotics, n (%)	3,514		3,353		161		0.495	N/A
No		2,921 (83)		2,784 (83)		137 (85)		
Yes		593 (17)		569 (17)		24 (15)		
Perioperative discharge type, n (%)	3,556		3,392		164		< 0.001	

*Independent-samples *t*-test.
ASA, American Society of Anesthesiologists; BMI, body mass index; DVT, deep venous thrombosis; PE, pulmonary embolism; SNF, skilled nursing facility.

Table II. Summary of patients within manipulation under anaesthesia (MUA) and non-MUA cohorts with their specific component designs (n = 2,878 knees) and implant fixation (n = 2,916 knees).

Variable	No MUA, n (%)	MUA, n (%)	Combined
Component type			
Posterior stabilized	775 (28)	33 (25)	808 (28)
Cruciate retaining	1,786 (65)	88 (68)	1,874 (65)
Total stabilized (hinged)	16 (1)	1 (1)	17 (1)
Condylar stabilized	171 (6)	8 (6)	179 (6)
Fixation method			
Press fit	775 (28)	48 (35)	823 (28)
Cemented	2,002 (72)	91 (65	2,093 (72)

Available details of numbers of the component types used and the method of fixation is provided in Table II.

Table III. Multivariable regression analysis of studied risk factors associated with manipulation under anaesthesia.

Factor	Odds ratio (95% CI)	p-value
Age	0.96 (0.94 to 0.98)	< 0.001*
BMI	0.94 (0.91 to 0.97)	< 0.001*
ASA score	0.83 (0.58 to 1.2)	0.317
Female (vs male)	0.88 (0.6 to 1.29)	0.514
CR (vs PS)	1.24 (0.82 to 1.89)	0.311
TS (vs PS)	1.48 (0.18 to 12.24)	0.715
CS (vs PS)	1.06 (0.46 to 2.44)	0.890
Cemented (vs. Press Fit)	0.92 (0.6 to 1.4)	0.692
Current or former smoker	0.68 (0.47 to 0.99)	0.042*
History of DVT/PE	1.14 (0.56 to 2.34)	0.711
Diabetes mellitus (Type 1 or 2)	1.15 (0.72 to 1.84)	0.563
Preoperative anticoagulation use	1.1 (0.44 to 2.74)	0.832
Preoperative narcotics use	0.94 (0.57 to 1.56)	0.811
Home healthcare service (vs. routine discharge)	0.63 (0.41 to 0.96)	0.033*
Skilled nursing facility/ inpatient rehabilitation facility (vs. routine discharge)	0.31 (0.11 to 0.88)	0.027*

*Statistically significant.
ASA, American Society of Anesthesiologists; BMI, body mass index; CI, confidence interval; CR, cruciate retaining; CS, condylar stabilized; DVT; deep venous thrombosis; PE, pulmonary embolism; PS, posterior stabilized; TS, total stabilized.

Results

There was a total of 3,556 TKAs after inclusion/exclusion criteria were applied. The characteristics are shown in Table I. Due to crossover coding information, some of the component and use of cement information was lost (Table II). Of the 3,556 TKAs, 164 (4.6%) underwent MUA.

The patient characteristics/comorbid conditions age, BMI, and smoking status were statistically significant related to a decreased incidence of MUA (Table I). For every one-year increase in age, the likelihood of MUA decreased by 4% (OR 0.96, 95% CI 0.94 to 0.98; p < 0.001). For every one-unit increase in BMI, the likelihood of MUA decreased by 6% (OR 0.94, 95% CI 0.91 to 0.97; p < 0.001). Similarly, current or former smokers were more likely to be in the non-MUA group (OR 1.47, 95% CI 1.01 to 2.14; p = 0.042).

The following patient characteristics/comorbidities were not associated with an increased rate of MUA: ASA score (OR 0.83, 95% CI 0.58 to 1.20; p = 0.317, multivariable logistic regression analysis), female sex (OR 0.88, 95% CI 0.60 to 1.29, p = 0.514, multivariable logistic regression analysis), history of DVT or PE (OR 1.14, 95% CI 0.56 to 2.34, p = 0.711, multivariable logistic regression analysis), diabetes mellitus (OR 1.15, 95% CI 0.72 to 1.84, p = 0.563, multivariable logistic regression analysis), preoperative anticoagulation use (OR 1.10, 95% CI 0.44 to 2.74, p = 0.832, multivariable logistic regression analysis), or preoperative narcotics use (OR 0.94, 95% CI 0.57 to 1.56, p = 0.811, multivariable logistic regression analysis) (Table III).

No statistically significant differences were seen in the rate of MUA for type of implant used or for the mode of fixation: CR implants (vs PS, OR 1.24, 95% CI 0.82 to 1.89; p = 0.311), TS implants (vs PS, OR 1.48, 95% CI 0.18 to 12.24, p = 0.715), CS implants (vs PS, OR 1.06, 95% CI 0.46 to 2.44; p = 0.890), and cemented implants (vs cementless, OR 0.92, 95% CI 0.60 to 1.40; p = 0.692).

The discharge disposition affected the rates of MUA. Of all patients, 1,867 patients (1,867 knees, 52.5%) were discharged home with self-care instructions and prescription for outpatient PT, 1,335 patients (1,335 knees, 37.5%) were given home

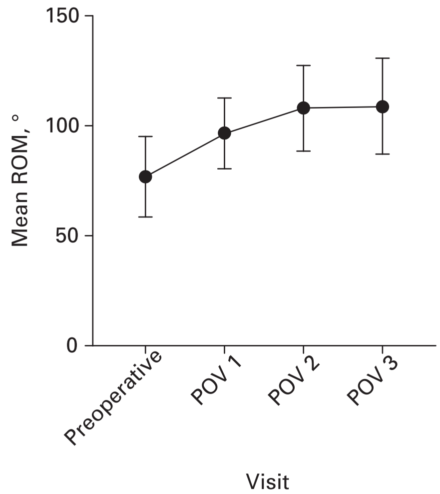

Fig. 2

Mean improvement in range of movement (ROM) (°) between pre-manipulation under anaesthesia and first, second, and third post-procedure clinic visits. Differences found between visits are reported in Table IV. Error bars represent SD. POV, postoperative visit.

Table IV. The post-manipulation under anaesthesia range of movement (analysis of variance with Tukey's post hoc test).

Comparison	Mean difference, ° (SD)	Adjusted p-value
Preoperative vs POV 1	19.36 (16.21)	< 0.001
Preoperative vs POV 2	30.27 (19.55)	< 0.001
Preoperative vs POV 3	33.62 (20.10)	< 0.001
POV 1 vs POV 2	12.23 (15.98)	< 0.001
POV 1 vs POV 3	15.86 (18.46)	< 0.001
POV 2 vs POV 3	5.22 (18.10)	0.992

POV, postoperative visit.

health care services/therapy, and 353 patients (10%) were sent to a subacute rehabilitation facility or skilled nursing facility for further care/therapy. Patients discharged to home health care were about 60% more likely to be in the non-MUA group when compared to those with a routine discharge home (OR 1.59, 95% CI 1.04 to 2.44; $p < 0.033$). Patients discharged to a skilled nursing facility (SNF) or inpatient rehab (IPR) were over three times more likely to be in the non-MUA cohort (OR 3.20, 95% CI 1.14 to 9.01; $p = 0.027$) (Table III).

ROM data were examined routinely in the postoperative period in to assess patients' improvements after MUA. The time from the index TKA to MUA was a mean of eight weeks (SD 2.09; 0.5 to 12.5). The mean ROM prior to MUA was 77.5° (SD 17.67°; 25° to 105°). Patients improved by a mean 32.81° (SD 19.85°; -15° to 90°) from pre-MUA ROM to the third post-operative visit ROM. Mean follow up time from MUA to last appointment was 20.01 weeks (SD 22.54; 1 to 40). There was a statistically significant improvement in ROM data at all stages compared with the pre-procedural ROM, except between the second and last post-MUA visit (Figure 2, Table IV).

Discussion

The literature has presented inconsistent findings with regard to the risk factors associated with stiffness after TKA. Risk stratification and patient education are paramount to obtaining satisfactory outcomes and for managing appropriate patient expectations. We sought to determine the impact of preoperative comorbid conditions, type of implant, use of cement, and discharge disposition on the rate of MUA after TKA. The information would provide the ability to risk-stratify and or provide reasonable expectations to patients, families, and insurers preoperatively.

The patients who underwent MUA were younger, had lower BMI, and were either current or former smokers. Other than smoking, these are patients who normally would have higher expectations for functional improvement. Factors that were found to be protective included a discharge to a skilled nursing facility or home with home health care services. Both of these groups would typically be associated with lower functioning patients.

Similar to our findings, Parvizi et al[12] showed that younger and lower BMI patients have been found in the literature were more likely to undergo MUA. More recently, Newman et al[9] showed an increase rate of MUA with younger patients. Those authors postulated that the increased rate in younger patients may be due to patient expectations and the requirement for more post-operative flexion in this population. Also contrary to our findings, Werner et al[13] and Issa et al[8] both showed an increased proportion of MUAs with smokers.

Unexpectedly, our patients who were discharged to skilled nursing facilities had lower rates of MUA than those discharged home. This seems contrary to past works that have high associations of readmission and complications with extended care facility (ECF) placement. Several studies have found higher overall complication rates and readmission rates with ECF placement compared to routine discharge home,[14-16] but these studies did not assess functional outcomes or stiffness. A select few studies examined the relationship of discharge location and stiffness; all showed no difference in functional outcomes and/or ROM gain between home and non-home discharge.[17-19] Only one of these studies was based on a United States cohort.[17] We were unable to find any previous study specifically evaluating discharge disposition and rates of MUA.

As mentioned, the literature has shown conflicting data on the influence of component type with postoperative stiffness. Our investigation showed no significant difference between implants with different levels of constraint. This finding was supported by four previous investigations. These studies found no difference in postoperative ROM between CR and PS implants.[8,20-22] A few studies have shown a decreased ROM in CR components compared to PS.[23-25] Proposed causes have been in relation to the intraoperative balancing of the posterior cruciate ligament during implantation of CR protheses.

Implant fixation was also examined due to increased interest in cementless prostheses in recent years.[26] There has been a paucity of data examining the evidence for cementless components in a specific populations. While cemented TKA is still the standard, there has been evidence of increased aseptic loosening in younger patients with more active lifestyles[27] and in the morbidly obese.[26] A recent prospective, randomized trial reported no significant differences in clinical outcome measures at four to six weeks, one year, or two years postoperatively, between cementless and cemented components.[28] Our analysis was the first to demonstrate no significant difference in the risk of proceeding to MUA between cemented and cementless implants, but this needs to be corroborated by prospective studies.

Although a certain proportion of patients developed stiffness in the postoperative period, the overall success of MUA was encouraging. Improvement in ROM was seen at all times after the MUA, demonstrating that patients did maintain improvement after their procedures in the short term. Long-term success of MUA is controversial with studies showing a potential for only temporary improvement[29] or increased rates of total knee revision.[13]

This study included patient outcome data from two sister hospitals across a five-year span, which included a total of 12 surgeons. These surgeons had various levels of experience and fellowship training. All surgeons followed identical institution-wide postoperative pathways that included preoperative patient education, standardized pain regimens and physiotherapy sessions. A variety of total knee systems were used. These attributes contribute to the generalizability of the study's results and this was a significant strength of the analysis.

There were definite limitations of this analysis. While the data did include patients from 12 surgeons across our institution with various approaches and level of experience, this allowed variations in the decision to undertake MUA. In general, all of the surgeons favoured use of MUA when a patient's ROM was less than 90° to 95° at six to eight weeks postoperatively. Also, there was no assessment of patient expectations in this study and should be investigated further with a follow-up study. No patient reported outcomes (PROs) or assessment of patient expectations were obtained in this study. In addition, there was no real way to assess if a patient had refused a manipulation or what the specifics were that caused the surgeon to take the patient to the operating room.

In conclusion, the at-risk population for MUA after TKA was younger, thinner patients and those who were either current or former smokers. Patients discharged to a care facility had a decreased rate of MUA compared with those who received routine home care. The constraint of the implant and the use of cement did not impact the rate of MUA. These data may be used to counsel patients about their likelihood of being required to undergo MUA for stiffness postoperatively.

Take home message

- Assessing for risk factors in the arthroplasty population provides clinicians the ability to risk-stratify patients in the preoperative period.
- Knee stiffness in the total knee arthroplasty (TKA) population can change the postoperative course of TKA.
- Younger and thinner patients may need additional education in order to decrease the chance of stiffness in the postoperative period.

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