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ORIGINAL ARTICLE

Key factors in determining surgical timing of total knee arthroplasty in osteoarthritic patients: age, radiographic severity, and symptomatic severity

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Abstract
Background Patient age, radiographic severity of osteoarthritis (OA), and severity of symptoms are typically considered as the three key factors in selecting the osteoarthritic patients for total knee arthroplasty (TKA). The purpose of this study was to evaluate the associations between the three selection criteria and the postoperative outcomes including patient satisfaction. We also attempted to determine whether the patients not fully satisfying the criteria are different from the typical candidates in postoperative outcomes.
Materials and methods Three hundred and eighty-three uncomplicated TKAs with 1-year follow-up data were included in this study. We evaluated three preoperative factors including age, radiographic severity of OA, and WOMAC pain and function scores as proxies of preoperative level of symptoms. Evaluation of the postoperative outcomes included WOMAC pain and function scores and the level of patient satisfaction. Regression analyses were used to investigate the associations between the preoperative factors and the postoperative outcomes. Comparative analyses of the postoperative outcomes were made between the typical candidates with all selection criteria and the groups of patients who did not meet one of the selection criteria.
Results Increasing age was associated with worse postoperative functional outcomes. Worse preoperative WOMAC pain and function scores were associated with worse postoperative WOMAC pain and function scores, and had a statistical tendency toward higher patient dissatisfaction. Compared to the typical candidates, the groups of patients who did not meet one of the selection criteria did not have worse postoperative outcomes. On the contrary, the group of younger age and the group with less severe preoperative symptoms were more likely to have better postoperative outcomes. The radiographic severity of OA had no significant associations with any of postoperative outcomes.
Conclusion This study indicates that, when considering TKA as a treatment option, orthopedic surgeons need to comprehend the selection criteria in an overall view to offer the best timing for optimal postoperative outcomes.

Keywords Total knee arthroplasty · Factors for surgical timing · Age · Symptoms · Radiographic severity

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Introduction

Total knee arthroplasty (TKA) has been established as a highly successful procedure for treating patients with advanced osteoarthritis (OA) [1–5]. Several factors play a crucial role in obtaining successful TKAs, and these include well-selected patients, appropriate implants, well-performed surgical procedures, and adequate postoperative

rehabilitation [6, 7]. Patient age, radiographic severity of OA, and severity of symptoms including response to other treatment modalities are typically considered as the three key factors in selecting the patients for TKA [8, 9]. In our practice, best candidates for TKA would be elderly patients with severe radiographic OA who have suffered from severe pain and functional impairment not adequately relieved by other treatment modalities.

However, more often than not, the situation where one or two of the three factors are not met occurs and the orthopedic surgeon is faced with challenging questions associated with the durability of TKA, the correctness of an established diagnosis to be causing the current symptoms, and postoperative patient satisfaction. For a young patient, the risks for future revision surgery owing to the limited durability of current TKA systems and inferior patient satisfaction from higher patient expectation of postoperative activities would be major concerns [9, 10]. If an elderly patient with severe symptoms and functional disabilities presents with relatively less radiographic severity of OA, the surgeon would be concerned over the possibility that the diagnosed osteoarthritis is not the underlying disease causing the current symptoms and disabilities. The subsequent concern would be the possibility of postoperative patient dissatisfaction. For an elderly patient with severe radiographic osteoarthritis who can still continue routine daily activities despite the chronic pain and deformity, the surgeon would be concerned about inferior patient satisfaction due to the relatively small amount of functional improvement after surgery [11]. Therefore, good patient selection for successful TKAs may be elusive even in the practice of a surgeon using well-defined selection criteria.

Information on the associations between the selection criteria and the postoperative clinical outcomes will be very helpful for a surgeon to recommend TKA at an optimal time-point for the patient with osteoarthritis of chronic nature. However, current literature lacks information on the relationship between the major preoperative factors for the decision to perform TKA and the clinical outcomes including level of patient satisfaction after the procedure [12, 13]. Thus, in this study, we aimed to investigate the associations between the three selection criteria (patient age, radiographic severity of OA, and severity of symptoms) and the clinical outcomes including postoperative patient satisfaction. We were particularly interested in determining how the patients who did not fully satisfy one of the criteria were different in the postoperative outcomes from the patients who met all three criteria. We hypothesized that these preoperative factors would be significantly associated with the postoperative clinical outcomes and that the patients not fully satisfying the criteria would have different postoperative outcomes from the patients for whom all the selection criteria were satisfied.

Materials and methods

Clinical information and plain radiographs of the knee joint were evaluated for 276 consecutive patients (438 knees) who had undergone primary TKA at the authors' institute from November 2003 to March 2005. Fifty-five knees in 36 patients were excluded for various reasons: a different diagnosis from osteoarthritis (20 knees, including 4 knees in 3 patients with post-infectious arthritis, 7 knees in 6 patients with post-traumatic arthritis, 8 knees in 5 patients with rheumatoid arthritis, and 1 with neuropathic arthropathy), periprosthetic infection (4 knees in 4 patients; all the patients underwent bilateral TKAs, thus excluding 8 knees in the evaluation), death unrelated to the surgery (4 knees in 2 patients), significant medical problems (11 knees in 7 patients) unrelated to the surgery including cardiovascular or cerebrovascular accidents, Parkinson's disease, and spine / hip fractures. Another 12 knees (8 patients) were excluded as the patients did not visit our clinic on the day appointed for 1-year follow-up. Consequently, 383 TKAs (in 240 osteoarthritic patients) with follow-up longer than 1 year were included in this study. There were 230 female patients and 10 male patients (370 and 13 knees, respectively). The mean age in years was 68.8, ranging from 54 to 82 [standard deviation (SD) = 6.0]. The mean height and weight were 151.9 cm (range = 138–174 cm, SD = 6.1) and 60.6 kg (range = 36–83 kg, SD = 9.0). The mean body mass index (BMI) was 26.2 kg/m^2 (range = 18.1–37.2 kg/m^2, SD = 3.5). All patients gave informed consent prior to being included in this study. This study was approved by the institutional review board of our hospital and performed in accordance with the ethical standards of the 1964 Declaration of Helsinki as revised in 2000.

All surgeries were performed by a single surgeon (one of the authors). Two hundred and eighty-six TKAs were performed as bilateral procedures in 143 patients, and the other 97 were done as a unilateral procedure. One hundred and ninety-eight knees were implanted with mobile bearing prosthesis (E-motion; Aesculap, Germany), and 185 knees were implanted with fixed bearing prosthesis (Genesis II; Smith & Nephew, USA). The approach was performed through medial parapatellar arthrotomy. In all cases, the patella was resurfaced, and implant fixation was carried out with cement.

All clinical data including demographic information were collected in the prospective manner by an independent investigator. Preoperative clinical status was assessed using the Western Ontario McMaster Universities Osteoarthritis Index (WOMAC) scales [14]. Assessment of

postoperative clinical outcomes at 1 year after surgery included the WOMAC scale and the level of patient satisfaction. The level of patient satisfaction was evaluated using the four-point grading system of the British Orthopaedic Association: enthusiastic, satisfied, noncommittal, and disappointed. Information on patient satisfaction was collected for 319 (83.2%) of the 383 knees.

Radiographic evaluations utilized standing anteroposterior, standing 45° flexion posteroanterior, lateral, and Merchant patellofemoral views of the knee, which were digitally acquired through the Picture Archiving and Communication System (PACS; Agfa, Belgium). The medial and lateral compartments of the tibiofemoral joint (TFJ) and the patellofemoral compartment were evaluated separately and assigned scores using the modified Ahlbäck radiographic scoring system [15]. The scores for the medial and lateral compartments of the TFJ were determined based upon the presence of joint space narrowing (1 point) or obliteration (2 points), tibial and/or femoral sclerosis (0.5 point each), osteophytes equal to or smaller than 1 cm (0.5 point) or greater than 1 cm (1 point), and joint subluxation (1 point) for a maximum total of 5 points. The score for the patellofemoral compartment was determined on the basis of the presence of narrowing (1 point) or obliteration (2 points), osteophytes equal to or smaller than 1 cm (0.5 point) or greater than 1 cm (1 point), translation of the patella (1 point), and attrition (1 point), also for a maximum total of 5 points.

Statistical analyses were conducted with SPSS for Windows statistical package (version 12.0; SPSS, Chicago, IL), and P value < 0.05 was considered significant. The associations between the preoperative factors and the postoperative outcomes were analyzed using the linear regression for the continuous outcome variables (the WOMAC pain and function scores) and the logistic regression for the categorical outcome variable (level of patient satisfaction). The preoperative factors included the patient age, radiographic severity represented by the scores of the modified Ahlbäck radiographic scoring system, and the severity of symptoms and functional impairments represented by the WOMAC scores (pain and function). Results of the linear regression analyses were presented with regression (beta) coefficient (β) and P value. In the logistic regression analysis, odds ratios (OR) with 95% confidence intervals were calculated, and the associations were considered significant when the 95% confidence interval around the OR did not include the number 1 and the P value was less than 0.05. When significant associations were found between the possible confounders and the postoperative outcomes, the confounding effects were controlled with the use of multivariate regression analyses. These factors included gender, body mass index (BMI), the patient category of the American Knee Society [A: unilateral or bilateral (opposite knee successfully replaced), B: unilateral (other knee symptomatic), and C: multiple arthritis or medical infirmity], whether a unilateral or bilateral procedure, the type of implant, and postoperative range of motion.

To determine whether the patients not fully satisfying the selection criteria had different postoperative outcomes, comparative analyses of the postoperative outcomes were done between the group of typical candidates with all selection criteria (age, radiographic severity, symptomatic severity) satisfied and the groups of patients who did not meet one of the selection criteria. The typical candidates were defined as the patients (1) whose age was 60 years or older, (2) who had severe radiographic OA (radiographic score of the modified Ahlbäck system 4.5 or greater), and (3) who had severe preoperative symptoms (the WOMAC total score was less than 50% of the full mark). The variables for postoperative outcomes were the WOMAC scores (pain and function) and the level of patient satisfaction. The four levels of patient satisfaction were dichotomized into the satisfied group (“enthusiastic” or “satisfied”) and the dissatisfied group (“noncommittal” or “disappointed”) for the comparisons. Statistical significance of the differences between the groups was determined with the Student t-test for numerical data with normality, Mann-Whitney U test for numerical data without normality, and chi-squared test for categorical data.

Results

In the regression analyses between the preoperative factors and the postoperative outcomes, the age and preoperative WOMAC scores were significantly associated with the postoperative outcomes whereas the radiographic OA score had no significant associations. The preoperative characteristics of the subjects including age, radiographic severity of OA, preoperative clinical scores, and postoperative outcome scores at 1-year follow-up are presented in Table 1. In the 319 knees for which patient satisfaction could be ranked, there were 107 knees (33.5%) in the enthusiastic category, 191 knees (59.9%) satisfied and 21 knees (6.6%) noncommittal. There were no knees in the disappointed category. The patient age was positively associated with the postoperative WOMAC function score ($\beta = 0.232$, $P < 0.001$), indicating that increasing age was associated with worse postoperative functional outcomes (Table 2). The preoperative WOMAC pain score was associated with the postoperative pain score ($\beta = 0.189$, $P = 0.002$) and had a statistical tendency toward a significant association with postoperative patient satisfaction (odds ratio = 0.866, $P = 0.097$) suggesting that patients with poor WOMAC pain scores were more likely to report

Table 1 Summary of the patient age, the radiographic scores of OA, the preoperative and postoperative (1 year) WOMAC scores

Parameter	Mean (SD)
Age (years)	68.8 (6.0)
Radiographic OA score (points)	5.4 (1.7)
Preoperative WOMAC score (points)[a]	
Pain (20)	11.8 (4.2)
Stiffness (8)	4.9 (2.0)
Function (68)	42.2 (12.7)
Total (96)	58.9 (17.3)
Postoperative WOMAC score (points)[a]	
Pain (20)	2.14 (2.7)
Stiffness (8)	1.5 (1.5)
Function (68)	15.6 (10.0)
Total (96)	19.3 (12.9)

SD Standard deviation, *OA* osteoarthritis, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index

[a] WOMAC can have a total score of a best (0) to 96 (worst)

dissatisfaction. The preoperative WOMAC function score was associated with the postoperative WOMAC function score ($\beta = 0.212$, $P < 0.001$).

Comparisons between the groups not satisfying one of the selection criteria and the group of the typical candidates revealed significant differences in outcome parameters except in the group not satisfying the radiographic criterion (Table 3). Of the 383 knees, 190 (49.6%) satisfied all three selection criteria while 193 (50.4%) did not meet one or two of the criteria. There were no cases that did not satisfy all three criteria. As the group not satisfying the age criterion had significantly better preoperative function scores, adjustment of their confounding effects was performed using the multivariate analysis of covariance (MANCOVA). The group not satisfying the age criterion had better postoperative WOMAC function score than the typical candidates (17.3 vs. 10.8, $P = 0.015$), and there was no knee reported in the dissatisfied category in this group, whereas 8.7% (14/161) of the typical candidates were reported in the dissatisfied category. The group not satisfying the symptomatic criteria had better postoperative WOMAC pain and function scores than the typical candidates (2.6 vs. 1.6, $P = 0.023$; 17.3 vs. 13.3, $P = 0.016$, respectively). In addition, the group not satisfying the symptomatic criteria had slightly lower proportion of patient dissatisfaction than the group of the typical candidates, but the difference was not statistically significant. (3.0 vs. 8.7%, $P = 0.130$).

Discussion

In this study, we sought to investigate the association between the postoperative outcomes and the preoperative factors that would be typically considered in determining surgical timing of TKA for osteoarthritis patients. The patient age, radiographic severity, and symptomatic severity taken with the responsiveness to other treatment modalities would be the commonly agreed selection criteria for determining the surgical timing of TKA in osteoarthritic patients. However, a variety of different clinical scenarios are encountered in practice, which imposes on the caring physicians the challenging question of when to recommend the surgical option with the aim of achieving the best postoperative outcomes. Few surgeons would hesitate to recommend TKA for a 65-year-old patient who presents with the radiographs displaying far advanced osteoarthritis and who has suffered from intractable knee joint symptoms that compromise daily activities. However, many surgeons would be reluctant to recommend the surgical option for patients who do not meet one or two of the selection criteria. In this study, 50.4% (193/383 knees) did not satisfy one or two selection criteria. This study provides valuable clues with which the doctors can

Table 2 Results of the regression analyses to evaluate the associations between the preoperative factors and the postoperative outcomes

Preoperative factor	PO WOMAC pain score		PO WOMAC function score[a]		Patient satisfaction	
	β coefficient	P value	β coefficient	P value	Odds ratio [95% CI]	P value
Age	0.101	0.118	0.232	<0.001	0.931 [0.849–1.021]	0.130
Radiographic OA score	−0.024	0.700	−0.078	0.193	1.119 [0.833–1.503]	0.456
Preoperative WOMAC score						
Pain	0.189	0.002	0.041	0.621	0.866 [0.730–1.027]	0.097
Function	−0.031	0.717	0.205	<0.001	1.018 [0.960–1.080]	0.551

The associations between the preoperative factors and the postoperative WOMAC scores were tested using the linear regression analysis, while the associations between the preoperative factors and patient satisfaction were tested using the logistic regression analysis

PO Postoperative, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index, *OA* osteoarthritis, *CI* confidence interval

[a] As the postoperative range of motion was associated with the postoperative WOMAC function score (β coefficient $= -0.179$, $P = 0.003$), the confounding effect was controlled with multivariate regression analysis

Table 3 Comparisons between the group of typical patients with all selection criteria satisfied and the groups of patients who did not satisfy one of the selection criteria

Parameters	Typical candidates[a] [$N = 190$ (49.6%)]	Patients not satisfying the age criterion [$N = 20$ (5.2%)]		Patients not satisfying the radiographic criterion [$N = 53$ (13.8%)]		Patients not satisfying the symptomatic criterion [$N = 77$ (20.1%)]	
	Mean (SD)	Mean (SD)	Significance[b] (*P*-value)	Mean (SD)	Significance[b] (*P*-value)	Mean (SD)	Significance[b] (*P*-value)
Age	70.3 (4.8)	56.9 (1.5)	<0.001	69.6 (4.9)	0.419	69.5 (5.7)	0.365
Radiographic OA score	6.1 (1.5)	5.7 (1.1)	0.609	3.5 (0.5)	<0.001	6.0 (1.3)	0.598
Preoperative WOMAC							
Pain (20)	13.3 (3.2)	12.7 (3.4)	0.385	13.8 (3.3)	0.364	7.2 (2.7)	<0.001
Function (68)	48.3 (8.5)	41.1 (6.8)	0.002	46.6 (10.4)	0.352	27.4 (5.5)	<0.001
Postoperative WOMAC							
Pain (20)	2.6 (3.1)	1.4 (2.6)	0.101	2.4 (2.7)	0.803	1.6 (2.2)	0.023
Function (68)	17.3 (10.0)	10.8 (10.1)	0.015	18.2 (11.5)	0.634	13.3 (9.3)	0.016
Proportion dissatisfied[c]	8.7% (14/161)	0% (0/16)	NA	8.9% (4/45)	0.968	3.0% (2/66)	0.130

SD Standard deviation, *OA* osteoarthritis, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index, *NA* not applicable

[a] Typical patients satisfied all three selection criteria: (1) age ≥61 years, (2) radiographic OA score ≥4.5, (3) preoperative WOMAC total score ≤50% of full mark

[b] Comparisons were made to the group of typical candidates

[c] Not all patients responded to this question. Therefore, calculation of the proportions and comparisons between the groups were done with the numbers of patients who responded to the question

accomplish the elusive task of determining surgical timing of TKA in osteoarthritic patients.

When a patient does not satisfy the age criterion, besides the risks for future revision surgery from the limited durability of current TKA systems, the surgeon would be concerned over the possibility that the patient will not be satisfied postoperatively due to higher patient expectation of postoperative outcomes. In the recent study by Elson et al. [9], the authors recommended avoiding surgery in the patients younger than 60 years based upon their finding of higher prevalence of postoperative residual pain in the patients younger than 60 years. However, in their study, the proportion of knees with rheumatoid arthritis as the underlying diagnosis was 12.2% (76/622) and their findings might not be directly applicable for OA patients. In contrast, our findings suggest that TKAs performed in too elderly patients reduce the probability of an excellent outcome. In the current study, increasing age was significantly associated with worse postoperative WOMAC function scores. In contrast, the patients not satisfying the age criterion (younger than 60 years) had better postoperative WOMAC function scores and no patient in this group was dissatisfied with the postoperative results, which was in contrast to the finding that the prevalence of postoperative dissatisfaction was 8.7% in the typical candidates (older than 60 years). Our findings are concordant with the recent study by Noble et al. [11] reporting that postoperative satisfaction was significantly better in the patients younger than 60 years old. This study indicates that surgeons can expect comparable or better postoperative outcomes including patient satisfaction in the patients not satisfying the age criterion (younger than 60 years). However, as this study does not include the information about the longevity of TKAs, we cannot deny the concern over the limited longevity which is taken into account in considering TKA for young patients.

If an elderly patient with severe symptoms and functional disabilities presents with relatively less radiographic severity of OA, the surgeon would be concerned over the possibility that the diagnosed osteoarthritis is not the underlying disease causing the current symptoms and disabilities. The subsequent concern would be the possibility of postoperative patient dissatisfaction. However, this concern does not seem to be supported by the findings in this study. We found that the radiographic severity of OA had no significant associations with the postoperative outcomes in the regression analyses and the group not satisfying the criterion of radiographic severity did not differ in any postoperative parameters. Our findings may defy the perception that performing TKA in osteoarthritic patients with less radiographic severity results in inferior postoperative outcomes. Previous studies documented that radiographic severity is not necessarily correlated with symptomatic severity [16–18]. However, it should be emphasized that all TKAs were performed on knees with radiographic evidence of advanced osteoarthritis, which

was identified by the complete obliteration of joint space or the preservation of less than 25% of joint space, and special attention was paid to verifying that the knee osteoarthritis caused the symptoms and disabilities.

For an elderly patient with severe radiographic osteoarthritis who can still continue routine daily activities despite the chronic pain and deformity, the surgeon would be concerned about inferior patient satisfaction due to the relatively small amount of clinical improvement after surgery. Subsequently the surgeon would be tempted to delay the surgery until the patient has symptoms and functional disabilities to the extent that they compromise his or her daily activities. Our study does not support this idea, but on the contrary, indicates that performing the surgery too late can reduce the probability of an excellent outcome. We found that poor preoperative WOMAC pain and function scores were significantly associated with worse postoperative WOMAC pain and function scores, respectively. The patients not satisfying the symptomatic criterion (i.e., patients with relatively better preoperative WOMAC functions scores) had better postoperative WOMAC pain and function scores than the typical candidates (Table 3). Our findings are in line with the previous studies reporting the positive correlation between preoperative and postoperative WOMAC scores [13, 19, 20].

This study has several limitations. First, the characteristics of our patient population should be considered in applying our findings to other patient populations. It has been documented in many previous studies that postoperative patient satisfaction after TKA is significantly associated with patient expectations, which can vary with the multiple facets of a patient population studied [11, 21–23]. In our study, the proportion of the patients regarding their postoperative results as unsatisfactory (noncommittal) was only 6.6%, and most (93.4%) of the patients regarded their replaced knees as satisfactory. This higher proportion of satisfied patients might reflect the nature of our patient population in which most of the patients were elderly (mean age, 68.8 years) and female (95.8%, 230/240) and might have had different expectations from less elderly or male patients. Second, we set the age of 60 years as the age criterion. Although the same age has been utilized as the cut-off point in recent studies [9, 11], patients younger than 60 years may not represent the typical young patients undergoing TKA for early advanced osteoarthritis. However, given that we tend to seek other alternatives (osteotomy or unicompartmental arthroplasty) for patients younger than 55 years, we believe the age criterion used in this study holds valid clinical implications for determining surgical timing in OA patients. Third, we used the WOMAC system as the parameter to represent the symptomatic severity. Though the WOMAC has been widely used to evaluate the postoperative outcomes after TKA, it might not be sensitive enough to reveal the detailed individual differences in symptoms and functions, particularly in Asian patients. Finally, the data presented in this study were obtained at the 1-year follow-up visits. Although clinical outcomes after TKA are known to be stable after 1 year, postoperative outcomes may change with longer follow-up evaluations, and the associations between the preoperative factors and postoperative factors can be altered.

Selecting the optimal surgical timing is crucial for successful outcomes of TKA in osteoarthritic patients. This study provides valuable information for the physicians facing the challenging question of when to recommend the surgical option of TKA for osteoarthritic patients with various clinical scenarios. Our findings indicate that it is not a good idea to delay the surgical option of TKA for fear of poor postoperative outcomes until the patients are very old with severely deteriorated functions and their radiographs find the knee joint destroyed severely. This study indicates that, when considering TKA as a treatment option, orthopedic surgeons need to view the selection criteria comprehensively to offer the best timing for optimal postoperative outcomes.

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