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Original article

Analysis of factors affecting operating time, postoperative complications, and length of stay for total knee arthroplasty: nationwide web-based survey

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Abstract
Background. This study aimed to clarify the impact of various factors on the operating time, postoperative complications, and length of stay (LOS) after total knee arthroplasty (TKA).
Methods. We identified 3577 TKAs performed in 345 hospitals in Japan from November 2006 to March 2007. We examined the patient characteristics, surgical procedure details, hospital and surgeon volumes, and outcome variables (operating time, postoperative complications, LOS).
Results. The average operating time was 127 ± 47 min. The rate of postoperative complications was 9.8%. The average LOS was 35.1 ± 15.9 days. In multivariate regression analyses, the average operating times were significantly shorter at hospitals with ≥50 cases per year compared to hospitals with <10 cases per year and for surgeons with ≥100 total cases compared to surgeons with <100 total cases. A longer operating time was associated with revision surgery and use of computer navigation. Significant predictors of postoperative complications were age, body mass index, and cerebrovascular disease. Shorter LOS was associated with higher hospital volume and use of a clinical pathway, whereas age, cardiovascular disease, and revision surgery increased the length of stay.
Conclusions. Postoperative complications following TKA mainly depended on patient-based factors and were not significantly affected by the surgeon's experience.

Introduction

Total knee arthroplasty (TKA) has an integral role in the treatment of severe knee joint diseases including osteoarthritis and rheumatoid arthritis. The procedure has been established as a safe, standard treatment.[1] Several factors are thought to influence the operative outcomes after TKA. Patient characteristics, including age and co-morbid conditions, are sources of variation for the operative outcomes and are often used as determining factors for whether a patient undergoes TKA. Procedural variations can be factors that affect the operative outcomes. Recently, a variety of novel surgical techniques have been introduced into orthopedic surgery, including minimally invasive surgery (MIS)[2–5] and computer-assisted surgery.[6–9] These techniques are expected to improve the results of surgery and patients' quality of life.

Volume–outcome relations have been one of the most discussed, but also disputed, subjects in orthopedic surgery during recent years. The possible associations between high case volumes and better patient outcomes in orthopedic surgery have been repeatedly investigated.[10] However, such a relation remains inconclusive for TKA.[11–16] Several studies demonstrated that hospital volume (HV) and surgeon volume (SV) were associated with mortality in TKA,[11,12] but other studies did not identify such associations.[13,14] Furthermore, several studies showed that postoperative complications were associated with HV[12–15] and SV,[13,16] whereas another study did not find such relations.[11]

In the present study, we hypothesized that the operative outcomes following TKA would be better in patients treated at high-volume hospitals, by high-volume surgeons, or with novel techniques including MIS or computer navigation. The aims of the present study were to analyze the associations between operative outcomes and multiple factors, including hospital/surgeon volume and procedural variations in TKA with adjustments for the patients' co-morbidities.

Methods

Sample collection

All data were obtained through a web-based questionnaire survey conducted from November 1, 2006 to

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March 31, 2007 with the cooperation of the Japanese Orthopaedic Association (JOA), with which almost all Japanese orthopedic centers are affiliated. A letter of invitation to participate in the survey was sent to all 2016 JOA member hospitals in September 2006. Hospitals that agreed to participate in the survey registered with the survey office via the Internet. Each orthopedic surgeon was able to log onto the website by entering a personal identification and password and then directly answer the questions on the screen by referring to the medical records of patients who underwent TKA during the survey period. Patients with a preexisting infection of the knee or a malignant bone tumor were excluded from the survey.

Hospital volume and surgical volume

The questionnaire assessed HV and SV. HV was identified as the number of TKAs performed in each hospital in 2005. Surgeon volume was defined as the number of TKAs performed by an operating surgeon over the course of his or her career. Surgeon volume was categorized into three groups (<100, 100–499, and ≥500), and each operating surgeon selected one of these categories.

Patient characteristics

The following patient characteristics were requested as patient-based covariates: age, sex, body mass index (BMI, in kg/m^2), diagnosis (osteoarthritis, rheumatoid arthritis, others), and co-morbid conditions [osteoporosis, diabetes mellitus, hypertension, chronic obstructive pulmonary disease (COPD), history of cerebrovascular disease, history of cardiovascular disease].

Surgical details

We requested the following details of the surgical procedures: (1) primary or revision TKA; (2) unilateral or bilateral TKA; (3) conventional or MIS; (4) whether computer navigation was used; (5) which type of knee prosthesis (cemented, uncemented, hybrid) was used; (6) whether patellar resurfacing was carried out; (7) whether bone graft was performed; and (8) operating time. Bilateral TKA included both simultaneous and two-stage bilateral TKA.

Postoperative complications

The occurrences of postoperative complications were clarified, including wound infection, implant infection, deep venous thrombus (DVT) or pulmonary embolism (PE), postoperative pneumonia, and others. DVT included asymptomatic DVT identified by vascular ultrasonography.

Postoperative course

The use of a clinical pathway was clarified for each case. The length of stay (LOS) was defined as the length of hospital stay following TKA. LOS after two-stage TKA was defined as LOS following the second TKA. The average LOS and in-hospital mortality were examined.

Statistical analyses

We examined the association between each outcome variable and each covariate using bivariate regression analyses. A statistical significance level of $P < 0.10$ was used as a screening cutoff. We then performed multivariate analyses including age, sex, HV, SV, and any of the significant covariates in the former bivariate analyses as independent variables.

For multivariate analyses, a generalized estimating equation (GEE)[17] was used to allow observations to be clustered by categorical variables. A proportional odds model fitted with a GEE was used to verify the effects of the independent variables on the operating time. A logistic regression model fitted with a GEE was used to examine the relations between the postoperative complications and independent variables. A proportional hazards model fitted with a GEE was adopted to clarify the factors affecting LOS.

We presented the strengths of the associations between dependent and independent valuables as odds ratios (ORs) or hazard ratios (HRs) and 95% confidence intervals (CIs) of each cluster compared to a reference group. The threshold for significance was a $P < 0.05$. All the statistical analyses were conducted using the software SAS version 9.1 (SAS Institute, Cary, NC, USA).

Results

Among the 2016 hospitals affiliated with the JOA, 710 registered to participate in this survey. Finally, a total of 3577 TKAs at 345 institutions were collected during the survey period.

Patient background and surgical details

The HV and SV data are presented in Table 1. The average HV among the 345 institutions in 2005 was 29.5. The patient characteristics are summarized in Table 2. Among the 3577 patients, more than 80% were female and were diagnosed with osteoarthritis. The surgical

Table 1. Hospital and surgeon volumes for total knee arthroplasty

Factor	No. of patients	No. of institutions
Hospital volume		
≤9	320	95
10–29	874	132
30–49	793	68
50–99	701	33
≥100	889	17
Surgeon volume		
≤99	612	
100–499	1578	
≥500	1387	

Table 2. Patients' backgrounds

Factor	Total
Sex	
Male	598
Female	2979
Age (years), mean (SD)	73.0 (8.0)
BMI[a](kg/m^2), mean (SD)	25.4 (4.0)
Diagnosis	
Osteoarthritis	2938
Rheumatoid arthritis	544
Others	95
Co-morbidity	
Osteoporosis	1121
Hypertension	1885
Diabetes mellitus	545
COPD	135
Cerebrovascular disease	211
Cardiovascular disease	663

BMI, body mass index; COPD, chronic obstructive pulmonary disease

details are summarized in Table 3. Revision surgery was undergone by 135 (3.8%) patients, and MIS was performed in 807 (22.6%) patients. Computer navigation was used in 81 (2.3%) cases.

Operating time

The average operating time in all patients was 127 ± 47 min. Those in each category are shown in Fig. 1.

In the initial bivariate analyses, diagnosis, revision surgery, computer navigation use, and patellar resurfacing exhibited significance with P values <0.1. MIS was

Table 3. Surgical details for total knee arthroplasty

Factor	No.
Primary or revision surgery	
Primary	3442
Revision	135
Unilateral or bilateral	
Unilateral	3269
Bilateral	308
Conventional or minimally invasive	
Conventional	2770
Minimally invasive	807
Use of computer navigation	
No	3458
Yes	81
Knee prosthesis	
Cemented	2928
Uncemented	420
Hybrid	197
Patellar resurfacing	
No	1365
Yes	2180
Bone graft	
No	3229
Yes	315

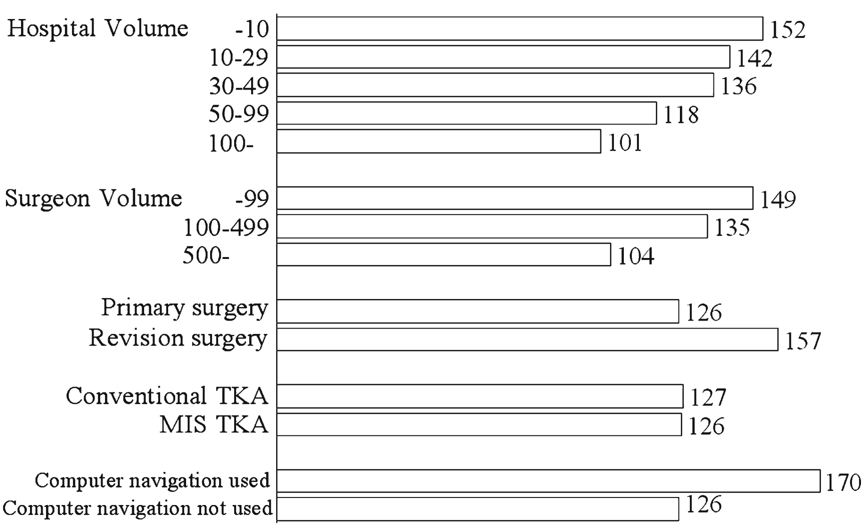

Fig. 1. Average operating time (minutes) in each category. *TKA*, total knee arthroplasty; *MIS*, minimally invasive surgery

not a significant factor affecting the operating time ($P = 0.95$).

In the proportional odds GEE model, both HV and SV were inversely associated with the operating time. Specifically, the average operating times were significantly shorter for hospitals treating ≥100 cases per year (OR 0.40) than for hospitals with <10 cases per year, and for surgeons with ≥500 total cases (OR 0.24) than for surgeons with <100 total cases. Revision surgery (OR 2.86) and use of computer navigation (OR 4.15) significantly increased the operating time (Table 4).

Postoperative complications

There were two (0.06%) in-hospital deaths. A total of 80 (2.3%) patients had wound infections, 5 (0.14%) had implant infections, 221 (6.4%) had a DVT or PE, 8 (0.23%) had postoperative pneumonia, and 45 (1.3%) had other complications. Overall, 341 (9.8%) patients had at least one complication. Figure 2 shows the rates of at least one complication in each category.

In the bivariate analyses, the P values for BMI, diagnosis, cerebrovascular disease, and patellar resurfacing were <0.1. Revision surgery ($P = 0.76$), MIS ($P = 0.37$), and computer navigation use ($P = 0.42$) did not exhibit significance.

In the logistic GEE regression, significant predictors of postoperative complications were age (OR 1.19), BMI (OR 1.25), and cerebrovascular disease (OR 1.90). Neither HV nor SV showed a significant association with postoperative complications (Table 5).

Length of stay

A clinical pathway was used in 2432 (68.0%) cases. The average LOS was 35.1 ± 15.9 days, and those in each category are shown in Fig. 3.

In the bivariate analyses, hypertension, cardiovascular disease, revision surgery, bone graft, and use of a clinical pathway were chosen as independent variables for subsequent multivariate analysis. No significant effects on LOS were identified for MIS ($P = 0.67$) or computer navigation use ($P = 0.70$). No significant difference in LOS was shown between bilateral and unilateral TKAs ($P = 0.80$).

Table 4. Proportional odds model for operating time

Category	OR	95%CI	P
Hospital volume			
≤9		Reference	
10–29	0.91	0.50–1.62	0.73
30–49	0.89	0.48–1.67	0.72
50–99	0.41	0.22–0.77	0.005
≥100	0.40	0.16–0.99	0.04
Surgeon volume			
≤99		Reference	
100–499	0.59	0.40–0.88	0.01
≥500	0.24	0.14–0.43	0.0001
Sex			
Female		Reference	
Male	1.28	1.06–1.54	0.01
Age: 10-year increase	0.86	0.76–0.96	0.01
Diagnosis			
Osteoarthritis		Reference	
Rheumatoid arthritis	0.79	0.60–1.05	0.10
Others	1.44	0.97–2.14	0.07
Primary or revision surgery			
Primary surgery		Reference	
Revision surgery	2.86	1.89–4.34	0.0001
Use of computer navigation			
No		Reference	
Yes	4.15	1.79–9.58	0.001
Patellar resurfacing			
No		Reference	
Yes	1.40	0.94–2.10	0.10

OR, odds ratio; CI, confidence interval

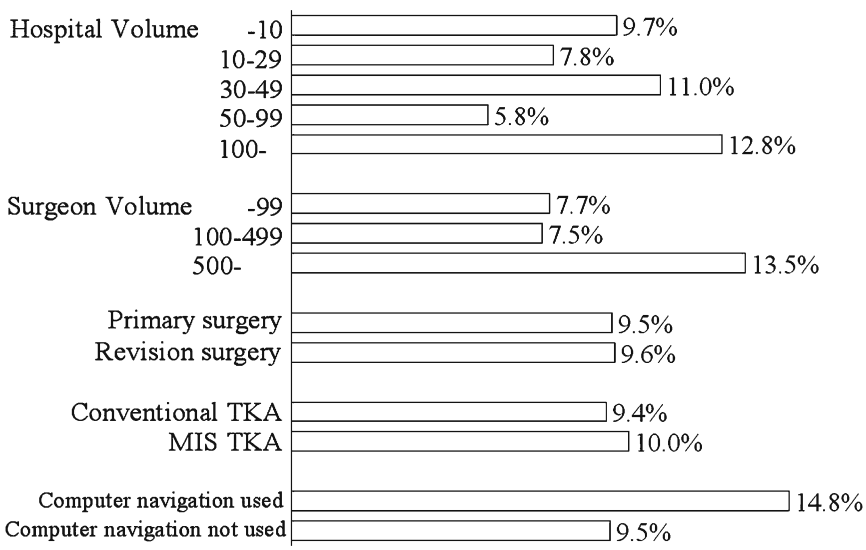

Fig. 2. Crude incidence of postoperative complications in each category

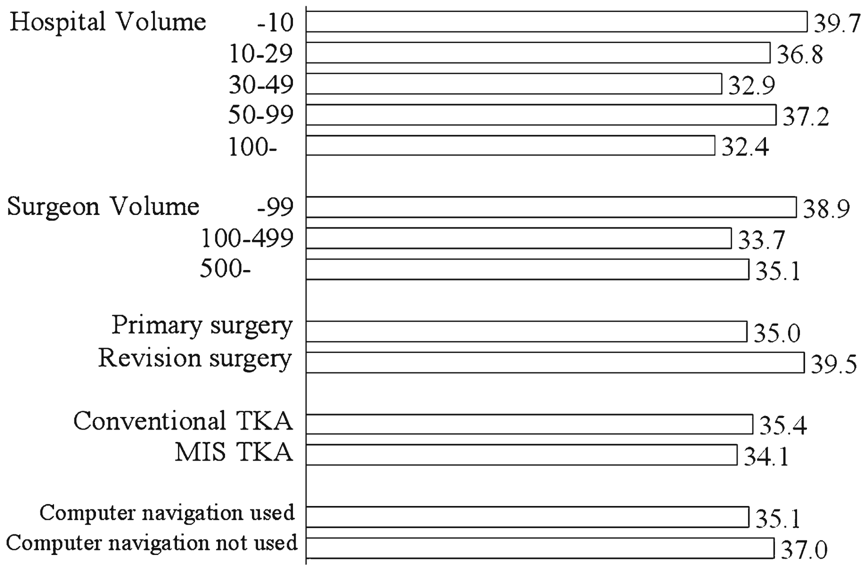

Fig. 3. Average length of stay (days) in each category

Table 5. Logistic regression model for postoperative complications

Factor	OR	95%CI	*P*
Hospital volume			
≤9		Reference	
10–29	0.57	0.31–1.03	0.06
30–49	0.83	0.41–1.70	0.62
50–99	0.59	0.28–1.26	0.17
≥100	0.80	0.27–2.34	0.68
Surgeon volume			
≤99		Reference	
100–499	1.40	0.83–2.37	0.21
≥500	1.17	0.66–2.07	0.60
Sex			
Female		Reference	
Male	0.80	0.56–1.14	0.22
Age: 10-year increase	1.19	1.01–1.41	0.04
BMI: 5 kg/m^2 increase	1.25	1.04–1.50	0.01
Diagnosis			
Osteoarthritis		Reference	
Rheumatoid arthritis	1.37	0.91–2.07	0.13
Others	0.90	0.32–2.50	0.83
Cerebrovascular disease			
No		Reference	
Yes	1.90	1.30–2.79	0.001
Patellar resurfacing			
No		Reference	
Yes	1.32	0.97–1.81	0.08

In the proportional hazards GEE model, short LOS was associated with high HV, although the trend was not linear. The HR of LOS in high-volume hospitals (≥100 cases) was 1.97 compared to the reference low-volume group (<10 cases). The significant predictors that increased LOS were age (HR 0.92), cardiovascular disease (HR 0.75), and revision TKA (HR 0.76). The use of a clinical pathway successfully decreased the LOS (HR 1.38) (Table 6).

Table 6. Proportional hazards model for length of stay

Factor	HR	95%CI	*P*
Hospital volume			
≤9		Reference	
10–29	1.09	0.80–1.49	0.59
30–49	1.59	1.10–2.30	0.010
50–99	1.18	0.84–1.64	0.34
≥100	1.97	1.26–3.08	0.003
Surgeon volume			
≤99		Reference	
100–499	1.18	0.91–1.52	0.21
≥500	0.82	0.60–1.12	0.21
Sex			
Female		Reference	
Male	1.26	1.09–1.45	0.002
Age: 10-year increase	0.92	0.86–0.98	0.01
Hypertension			
No		Reference	
Yes	0.96	0.87–1.05	0.35
Cardiovascular disease			
No		Reference	
Yes	0.75	0.62–0.91	0.003
Primary or revision surgery			
Primary		Reference	
Revision	0.76	0.60–0.95	0.010
Bone graft			
No		Reference	
Yes	0.77	0.57–1.04	0.09
Use of a clinical pathway			
No		Reference	
Yes	1.38	1.14–1.65	0.0007

HR, hazard ratio

Discussion

Volume–outcome relations

In previous volume–outcome studies, the associations between HV or SV and operative outcomes for TKA remained inconclusive. Katz et al.[13] reported that HV and SV were both inversely associated with the rates of postoperative pneumonia, PE, and deep infection following TKA. Kreder et al.[14] documented that HV was associated with the rates of readmission for infection, LOS, and in-hospital complications. Hervey et al.[11] confirmed a significant association between HV and mortality but did not identify any significant relation between HV or SV and the postoperative complication rate.

In the present study, patients treated by high-volume surgeons or at high-volume hospitals were likely to have a shorter operating time. On the other hand, no significant associations between HV or SV and postoperative complications were confirmed. These results indicate that experienced surgeons can quickly terminate the operation but cannot necessarily reduce adverse events.

Shorter LOS was mainly associated with HV and not with SV. This may arise because hospital factors, including in-hospital care and use of a clinical pathway, rather than the surgeon's experience affect the LOS.

Respective roles of surgeons' experience

Our results indicated that early postoperative complications mainly depended on patient-based factors and were not significantly affected by the surgeon's experience. However, we must discuss these results carefully because the indicators used in the present study do not tell the whole story of the surgical outcomes for TKA.

Avoiding postoperative complications and shortening the LOS are essential but are not the goal of surgery. TKA aims to improve the patient's knee function, physical activity, and overall quality of life. In future studies, such patient-oriented outcomes should be evaluated in long-term surveys.

Computer navigation and MIS

Computer navigation systems visualize positional information for surgical implants relative to bone on a computer display, which improves surgical accuracy.[7] Studies showed that use of computer navigation was associated with improved prosthetic alignment compared to that achieved with standard instrumentation.[8,9] Dutton et al.[9] reported that a computer-assisted MIS TKA group (n = 52) had a longer operating time and shorter LOS than a conventional TKA group (n = 58). Our results indicated that computer navigation-assisted TKA required a longer operating time but was not significantly associated with postoperative complications or LOS. However, this study showed that the current utilization rate of computer navigation is low (2.3%) in Japan. Therefore, if this method becomes more popular, its efficacy will be demonstrated more clearly.

Minimally invasive surgery has been reported to be associated with less postoperative pain, greater range of motion, and earlier recovery of knee function.[3–6] In the present study, there was no difference between conventional and MIS TKA regarding the postoperative complication rates and LOS. However, we must discuss these results carefully. First, MIS TKA has several variations, and they were not clearly differentiated in the present multicenter study. Second, this novel technique is expected to improve long-term outcomes, including the patient's overall quality of life, which were not evaluated in this study.

Limitations

Several limitations of our data should be acknowledged. The incidence of DVT might be affected by the differences in diagnostic criteria, including ultrasonography and venography.

This study was based on convenient samples collected from only 17% of the institutions affiliated with the JOA. The 2016 institutions include rehabilitation hospitals and long-term care hospitals. Supposedly, a substantial number of nonrespondents did not perform a TKA during the survey period of 5 months. The annual number of TKAs performed in Japan is estimated at about 50 000 (unpublished data). Therefore, the number of TKAs during 5 months is estimated about 20 000, and the coverage rate of population in this study is estimate about 18% (3577/20 000). The ability of the samples to represent the population as a whole might be limited. One of the causes of this low coverage rate might be that data entry in this survey was not compulsory but was done on a voluntary basis, and no incentives were paid for participation. This may have led to a self-selection bias; surgeons with poor outcomes might have declined to present their case(s).

Conclusion

With regard to TKA, high-volume hospitals and surgeons were more likely to have shorter operating times. However, postoperative complications mainly depended on patient-based factors and were not significantly affected by the surgeon's experience**.** In the next stage of volume–outcome research on TKA, long-term outcomes should be evaluated to clarify further the respective roles of surgeons' experience.

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