Original Article

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Comparison of Short-Term Complications of General and Spinal Anesthesia for Primary Unilateral Total Knee Arthroplasty

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Purpose: To compare the occurrences of perioperative complications of two anesthetic techniques (general anesthesia [GA] and spinal anesthesia [SA] in patients undergoing primary unilateral total knee arthroplasty (TKA).

Materials and Methods: Patients who underwent unilateral primary TKA due to osteoarthritis from January 2005 to January 2014 were retrospectively reviewed. They were divided into two groups: GA (n=490) and SA (n=746). The operation duration, length of perioperative stay in the operation room and occurrences of adverse events in postoperative 30 days (mean, 29.7±3.1 days) were compared. Before multivariate linear or logistic regression analysis, different baseline characteristics were adjusted in the statistical models.

Results: There were significant intergroup differences in mean age (GA, 68.4±7.2 years; SA, 70.7±7.5 years; p<0.001) and mCCI (GA, 3±1.4; SA, 3.2±1.5; p<0.001). The GA group required longer preoperative room time (+9.4 minutes; p<0.001), postoperative room time (+12.7 minutes; p<0.001), and postoperative hospital stay (+2.5 days; p=0.001) and had more surgical site infections (5 [1%] vs. 0 [0%]; p=0.005) and blood transfusion (205 [41.8%] vs. 262 [35.1%]; p=0.01). No differences in operative duration and other adverse events were identified.

Conclusions: We should cautiously consider that GA may be associated with slightly increased preoperative and postoperative room times, postoperative hospital stay, transfusion and surgical site infection rates in primary unilateral TKA.

Keywords: **Knee, Arthroplasty, Anesthesia, General, Spinal, Complications**

Introduction

Primary total joint arthroplasty is generally performed under general anesthesia (GA) or spinal anesthesia (SA). Historically, GA has been considered the gold standard for hip and knee arthroplasty. However, total hip and knee arthroplasty is now commonly performed under SA, especially for the elderly patient with comorbidities[1)]. The optimal anesthetic technique for hip and knee arthroplasty remains controversial.

Several studies have reported advantages of SA, such as decreased blood loss and infection, need for transfusion, and thromboembolic events compared with GA[2-5)]. In contrast, Moiniche et al.[6)] reported that regional anesthesia may not be advantageous. SA and epidural anesthesia may cause hypotension, motor blockade, urinary retention and pruritus[7)]. Lessire et al.[8)] reported a significant decrease in cardiac output in patients undergoing total hip arthroplasty under GA with epidural augmentation.

The purpose of this study was to compare perioperative room time and adverse events in thirty days following primary unilateral total knee arthroplasty (TKA) among patients who underwent the surgery under GA or SA.

The primary hypothesis of this study was that the incidence of adverse events and perioperative room time would not differ be-

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tween patients undergoing primary elective unilateral TKA using two types of anesthesia after adjustment for patient demographics.

Materials and Methods

1. Patient Selection and Demographics

Patients who underwent primary TKA due to osteoarthritis from January 2005 to January 2014 in our institution were included and evaluated. Exclusion criteria were 1) any history of infection, fracture, or dislocation of the involved joint, 2) inflammatory joint disease including rheumatoid arthritis, and 3) bilateral TKA. Most primary bilateral TKAs were performed with a 1 week interval between procedures on each side. Thus, the patients who underwent bilateral TKA were excluded to avoid statistical bias and interpretation error. The list of the patients was collected by the medical record team according to the recorded operation code. Orthopedic residents investigated the event of complications. The anesthetic record was made by the anesthesiologist himself or an anesthetic nurse.

A total of 1,581 patients were operated from January 2005 to January 2014. Of those, 1,236 patients were finally enrolled and divided into the GA group (n=490) and SA group (n=746).

Patient demographics including age, sex, height, and weight were evaluated via medical records. The mean body mass index (BMI) was calculated. Based on the available comorbidity data in the medical records, a modified Charlson Comorbidity Index (mCCI)[9] was generated. The mCCIs have been shown to be similar in efficacy to the original Charlson Comorbidity Index[9,10]. Underlying diseases were scored to calculate the mCCI, as follows: 1 point for acute myocardial infraction, congestive heart failure, peripheral vascular disease, cerebrovascular accident, dementia, chronic obstructive pulmonary disease, and diabetes mellitus; 2 points for hemiplegia and end-stage renal disease; 3 points for ascites or varices; and 6 points for cancer. One point was added for each decade after 40 years of age (Table 1).

2. Anesthesia, Surgical Techniques, and Rehabilitation Protocol

The decision to use GA or SA was at one senior anesthesiologist's discretion based on patient age, comorbidities, past medical history, and operative risk stratification. SA was not performed in patients with bleeding tendency, severe hypovolemia, increased intra-cranial pressure, severe aortic stenosis or mitral valve stenosis, sepsis and the refusal of the anesthesia. In some cases (aortic stenosis or previous lumbosacral surgery), GA was preferred over SA. If the patient did not have contraindicated conditions for SA, then the type of anesthesia was determined considering predicted complications, surgical schedule, and patient's preference. Older patients with a greater number of comorbidities were more likely to receive SA.

For patients in the SA group, 8–12 mg of 0.5% hyperbaric bupivacaine was injected into the subarachnoid space at the L3–4 interspace in the lateral decubitus position. The hyperbaric bupivacaine dose was determined by height and weight. Intravenous sedation using propofol was performed in the SA group during the operation. It was also used for intubation in the GA group. After intubation, GA was maintained with nitrous oxide in combination with oxygen, desflurane, and fentanyl. Rocuronium bromide was used as a muscle relaxant. The operative technique was not different in accordance with the anesthetic technique.

All operations were performed by one senior author. The press-fit condylar TKA (PFC; Mitek, Johnson & Johnson, Raynham, MA, USA) and Scorpio NRG (Stryker Inc., Mahwah, NJ, USA) were used. The medial parapatellar approach was used in all cases. Bone resection of the tibial plateau and distal femur was performed using a measured resection technique. Proximal tibial osteotomy was performed using an extramedullary alignment device along the longitudinal axis of the tibia. The proximal tibial posterior slope was fixed as 0 degree. A trial insert was applied to check varus/valgus instability, patellar tracking, and instrumental lift-off. Instrumental lift-off due to a narrow flexion gap was managed by posterior cruciate ligament release or adding a

Table 1. Modified Charlson Comorbidity Scoring System

Assigned weights for diseases[a]	Condition
1	Myocardial infarction
1	Congestive heart failure
1	Peripheral vascular disease
1	Cerebrovascular accident
1	Dementia
1	Chronic obstructive pulmonary disease
1	Diabetes
2	Hemiplegia
2	End-stage renal disease
3	Ascites or varices
6	Cancer

[a]Assigned weights for each condition that a patient has. The total equals to scores. For each decade >40 years of age, a score of 1 is added to the above score.

posterior tibial slope. Patellar resurfacing was not performed in all cases.

Low-molecular-weight heparin was used beginning postoperative day 1 and stopped 7 days postoperatively. The straight leg elevation exercise was started on the day of operation. Continuous passive range of motion (ROM) exercise and partial weight bearing was allowed after removal of negative suction drainage (2 or 3 days postoperatively). Full weight bearing was started 7 days postoperatively.

3. Operation Duration and Length of Perioperative Stay in the Operation Room

Operation duration and perioperative and postoperative stay were assessed using anesthetic records. Preoperative stay was defined as the time between arrival of patients into the operation room and the start of an incision. The operation duration was defined as the time between the first incision and wound closure. Postoperative stay was defined as the time between completion of wound closure and transfer of patients from the operation room. All SA was performed in the operation room. Hospital stay was defined as the number of days from admission to discharge.

4. Adverse Events

Patients with no complications were discharged 2 weeks postoperatively. Postoperative follow-up was performed 3 and 4 weeks postoperatively. All adverse events up to 4 postoperative weeks were analyzed. Mean follow-up period for perioperative complication analysis was 29.7±3.1 days. The follow-up rate until thirty postoperative days was 99.3%. Major complications were classified as follows: death, ventilator use for >48 hours, unplanned intubation, stroke or cerebrovascular accident, thromboembolic event, surgical site infection (SSI) , sepsis or septic shock, cardiac arrest, myocardial infarction, acute renal failure, return to the operating room, wound dehiscence, prosthesis failure, and peripheral nerve injury. Minor complications were classified as follows: urinary tract infection, pneumonia, progressive renal insufficiency, readmission, transfer to intensive care unit, etc. (dysuria, hematochezia, erosive gastritis, paroxysmal supraventricular tachycardia, and pulmonary congestion).

5. Statistical Analysis

Preoperative demographics were compared between the two groups using independent *t*-tests or Mann-Whitney *U*-tests for continuous variables and chi-square tests or Fisher exact tests for categorical variables.

For comparison of perioperative room times, length of stay, blood transfusion, and adverse events according to the type of anesthesia, a bivariate linear regression was performed. Multivariate linear or logistic regression analysis was performed for each outcome variable after adjustment for age and mCCI. Statistical analyses were performed using IBM SPSS ver. 24.0 (IBM Co., Armonk, NY, USA) with a confidence interval (CI) of 95%.

Table 2. Demographic Characteristics and Comorbidities of Patients

Variable	Total (n=1,236)	General anesthesia (n=490)	Spinal anesthesia (n=746)	p-value[a)]
Overall (%)	100	40	60	
Age (yr)				<0.001
<55	40 (3.2)	18 (3.7)	22 (2.9)	
55–64	243 (19.7)	118 (24.1)	125 (16.8)	
65–74	620 (50.2)	265 (54.1)	355 (47.6)	
≥75	333 (26.9)	89 (18.2)	244 (32.7)	
Mean±SD	69.8±7.5	68.4±7.2	70.7±7.5	<0.001
Sex				0.855
Male	125 (10.1)	51 (10.4)	74 (9.9)	
Female	1111 (89.9)	439 (89.6)	672 (90.1)	
BMI (kg/m^2)				0.212
<25	433 (35)	158 (32.2)	275 (36.9)	
25–29.9	595 (48.1)	254 (51.8)	341 (45.7)	
30–34.9	179 (14.5)	67 (13.7)	112 (15)	
≥35	29 (2.3)	11 (2.2)	18 (2.4)	
Mean±SD	26.6±4	26.7±3.7	26.6±4.2	0.264
mCCI				0.001
0–2	410 (33.2)	189 (38.6)	221 (29.6)	
3	457 (37)	178 (36.3)	279 (37.4)	
≥4	369 (29.9)	123 (25.1)	246 (33)	
Mean±SD	3.1±1.5	3.0±1.4	3.2±1.5	<0.001
Operative site				0.829
Right	607 (49.1)	243 (49.6)	364 (48.8)	
Left	629 (50.9)	247 (50.4)	382 (51.2)	

Values are presented as number (%).
SD: standard deviation, BMI: body mass index, mCCI: modified Charlson Comorbidity Index.
[a)]p-values were derived from independent *t*-tests or Mann-Whitney *U*-tests for continuous variables and chi-square tests or Fisher exact tests for categorical variables.

Results

1. Patient Demographics

Endotracheal GA was performed in 490 of 1,236 patients (mean age, 68.4±7.2 years [range, 45 to 89 years]; 51 males and 439 females), and SA was performed in 746 of 1,236 patients (mean age, 70.7±7.5 years [range, 46 to 92 years]; 74 males and 672 females). There was a significant intergroup difference in the mean age (p<0.001), but not in sex distribution (p=0.855). There was a significant difference in the mCCI (3.0±1.4 in the GA group and 3.2±1.5 in the SA group; p<0.001). Mean BMI was not significantly different between the groups (p=0.264). There was no significant difference in the operative site (GA group: right, 243, left, 247; SA group: right, 364, left, 382; p=0.829) (Table 2).

2. Operation Duration and Length of Perioperative Stay in the Operation Room

On multivariate analysis, GA was associated with increased preoperative room time (+9.4 minutes [95% CI, +6.7 to +12.2]; p<0.001) and postoperative room time (+12.7 minutes [95% CI, +10.4 to +15.1]; p<0.001). The operation duration was 112.1±21.6 minutes (range, 60 to 235 minutes) in the GA group and 111.4±15.4 minutes (range, 70 to 215 minutes) in the SA group. There was no significant difference in the multivariate analysis (p=0.717). Postoperative hospital stay was significantly longer in the GA group than in the SA group (+2.5 days in the GA group [95% CI, +1.1 to +3.9]; p=0.001) (Table 3).

3. Adverse Events

On multivariate analysis, the incidence of blood transfusion was significantly increased in the GA group (205, 41.8%) than in the SA group (262, 35.1%) (odds ratio [OR], 1.077 [95% CI, 1.018 to 1.138]; p=0.01). The GA group exhibited a higher incidence of SSI (5 [1%] vs. 0 [0%]) (OR, 1.010 [95% CI, 1.018 to 1.138]; p=0.005).

The incidences of other adverse events (death, ventilator use for more than 48 hours, unplanned intubation, stroke or cerebrovascular accident, thromboembolic event, sepsis or septic shock, cardiac arrest, myocardial infarction, acute renal failure, return to the operating room, wound dehiscence, prosthesis failure, peripheral nerve injury, urinary tract infection, pneumonia, progressive renal insufficiency, readmission, and transfer to intensive care unit) did not differ between the two groups (Table 4).

Discussion

The purpose of this study was to compare perioperative room times, adverse events in thirty days following primary unilateral TKA performed using either GA or SA. The principal finding of our study was that GA was associated with increased preoperative and postoperative room times, postoperative hospital stay, SSI rate, and requirement for blood transfusion.

The type of anesthesia is an important issue for better outcomes of surgery. Several studies have reported benefits of SA, including reduction in thromboembolic events, blood transfusion, and the potential for use in postoperative pain management[2,11,12]. However, disadvantages of SA in terms of hemodynamic compromise have also been reported[6,7]. In addition, concerns over the use of SA include the potential for delayed operation start due to technical difficulties, procedure failure, and less optimal muscle relaxation, which makes surgical site exposure and adequate placement of the prosthesis more difficult.

The postoperative room time following GA is dependent on the recovery of spontaneous respiration and muscle relaxation. In contrast, this is not necessary in SA. Thus, postoperative room time following GA is usually longer than that following

Table 3. Operating Room Time and Length of Stay According to Type of Anesthesia

Variable	General anesthesia (n=490)	Spinal anesthesia (n=746)	Bivariate linear regression		Multivariate linear regression[a]	
			Beta[b] (95% CI)	p-value	Beta[b] (95% CI)	p-value
Preop room time (min)	65.4±32.2	56.4±16.1	9.01 (6.29 to 11.73)	<0.001	9.42 (6.67 to 12.17)	<0.001
Operative time (min)	112.1±21.6	111.4±15.4	0.71 (–1.36 to 2.78)	0.499	–0.38 (–2.44 to 1.68)	0.717
Postop room time (min)	56.1±21.7	43.9±19.6	12.23 (9.9 to 14.57)	<0.001	12.74 (10.39 to 15.1)	<0.001
Postop length of hospitalization (day)	27.4±14.1	25.6±11.3	1.84 (0.41 to 3.26)	0.012	2.49 (1.07 to 3.91)	0.001

Values are presented as mean±standard deviation.

CI: confidence interval, Preop: preoperative, Postop: postoperative.

[a]Multivariate linear regression analysis was performed for each outcome variable adjusted for age and modified Charlson Comorbidity Index.

[b]Unstandardized beta coefficient represents unit change in the outcome variable of general anesthesia compared to that of spinal anesthesia.

Table 4. Postoperative Adverse Events According to Type of Anesthesia

Variable	General anesthesia (n=490)	Spinal anesthesia (n=746)	Bivariate linear regression		Multivariate linear regression[a]	
			OR[b] (95% CI)	p-value	OR[b] (95% CI)	p-value
Any adverse event	221 (45.1)	280 (37.5)	1.367 (1.085 to 1.724)	0.008	1.092 (1.032 to 1.155)	0.002
Any severe adverse event	14 (2.9)	14 (1.9)	1.538 (0.721 to 3.282)	0.261	1.015 (0.998 to 1.032)	0.089
Death	1 (0.2)	1 (0.1)	1.524 (0.060 to 38.587)	0.766	1.001 (0.997 to 1.006)	0.605
Ventilator use for more than 48 hours	2 (0.4)	1 (0.1)	3.053 (0.292 to 65.807)	0.363	1.004 (0.998 to 1.009)	0.211
Unplanned intubation	2 (0.4)	1 (0.1)	3.053 (0.292 to 65.807)	0.363	1.004 (0.998 to 1.009)	0.211
Stroke or cerebrovascular accident	0 (0)	1 (0.1)	N/A		0.999 (0.996 to 1.002)	0.515
Thromboembolic event	1 (0.2)	4 (0.5)	0.379 (0.019 to 2.574)	0.387	0.998 (0.991 to 1.005)	0.589
Surgical site infection	5 (1)	0 (0)	N/A		1.010 (1.003 to 1.018)	0.005
Sepsis or septic shock	0 (0)	0 (0)	N/A			
Cardiac arrest	1 (0.2)	1 (0.1)	1.524 (0.060 to 38.587)	0.766	1.001 (0.997 to 1.006)	0.605
Myocardial infarction	1 (0.2)	1 (0.1)	1.524 (0.060 to 38.587)	0.766	1.001 (0.996 to 1.006)	0.696
Acute renal failure	1 (0.2)	4 (0.5)	0.379 (0.019 to 2.574)	0.387	0.998 (0.991 to 1.005)	0.564
Return to the operating room	1 (0.2)	0 (0)	N/A		1.002 (0.999 to 1.006)	0.177
Wound dehiscence	5 (1)	3 (0.4)	2.553 (0.624 to 12.494)	0.201	1.007 (0.997 to 1.016)	0.157
Prosthesis failure	1 (0.2)	1 (0.1)	1.524 (0.060 to 38.587)	0.766	1.001 (0.997 to 1.006)	0.605
Peripheral nerve injury	1 (0.2)	1 (0.1)	1.524 (0.060 to 38.587)	0.766	1.001 (0.996 to 1.006)	0.655
Any minor adverse event	218 (44.5)	280 (37.5)	1.334 (1.058 to 1.682)	0.015	1.085 (1.025 to 1.148)	0.005
Blood transfusion	205 (41.8)	262 (35.1)	1.329 (1.051 to 1.679)	0.017	1.077 (1.018 to 1.138)	0.01
Urinary tract infection	1 (0.2)	3 (0.4)	0.506 (0.025 to 3.969)	0.556	0.998 (0.992 to 1.005)	0.58
Pneumonia	3 (0.6)	4 (0.5)	1.143 (0.224 to 5.205)	0.862	1.003 (0.994 to 1.011)	0.56
Progressive renal insufficiency	1 (0.2)	1 (0.1)	1.524 (0.06 to 38.587)	0.766	1.000 (0.996 to 1.005)	0.875
Readmission	4 (0.8)	4 (0.5)	1.527 (0.359 to 6.484)	0.551	1.003 (0.994 to 1.013)	0.475
Transfer to intensive care unit	6 (1.2)	6 (0.8)	1.529 (0.476 to 4.914)	0.464	1.007 (0.996 to 1.018)	0.232
Etc. (dysuria, acute gastroenteritis, paroxysmal supraventricular tachycardia, and pulmonary congestion)	14 (2.9)	15 (2)	1.433 (0.678 to 3.011)	0.339	1.015 (0.997 to 1.032)	0.098

Values are presented as frequency (%).
OR: odds ratio, CI: confidence interval, N/A: not available.
[a]Multivariate logistic regression analysis was performed for each adverse event adjusted for age and modified Charlson Comorbidity Index.
[b]Odds ratio represents the odds that each adverse event will occur in the general anesthesia group compared to that in the spinal anesthesia group.

SA. However, the preoperative room time in the GA group was significantly longer than that in the SA group in this study. In the GA group, the elderly patients, especially those who had severe comorbidity, necessitated careful dosage calculation and longer induction time to prevent hemodynamic fluctuation and a sudden decrease of cardiac output[13,14]. In our institution, there is a trend of using more monitoring devices and longer induction time for geriatric patients who undergo GA; however, this is subject to the anesthesiologist's judgement in general and thus our findings might not be applicable to the other hospitals.

Our findings suggested no difference in the operation time between the two groups. The type of anesthesia used had a minimal effect on the TKA procedure.

GA was associated with the longer postoperative hospital stay. This may because if a patient had a postoperative complication, discharge was delayed due to the need of intensive pain control or more rehabilitation. Detailed causes of delayed discharge could not be clearly compared between the two groups because most of

early postoperative clinical outcomes including ROM and pain visual analog scale (VAS) score were not available on the medical records, which is one of the limitations of this study.

The SSI rate was significantly high in the GA group. Some studies associated total hip or knee replacement under GA with a higher risk of SSI compared with epidural anesthesia or SA[15,16]. Although correlation between GA and the risk of SSI has not been established, several studies have demonstrated higher incidences of SSI after GA. GA results in a higher level of stress responses because it does not completely block afferent inputs and autonomic responses[17]. Moreover, vasoconstriction under GA impairs tissue perfusion and decreases tissue oxygen tension[18]. Volatile anesthetics and opioids impair neutrophil, macrophage, dendritic cell, T-cell, and natural killer cell functions, and thus diminish host defenses[19]. In contrast, epidural anesthesia or SA provides a sympathetic blockade, and greater vasodilatation could result in improved tissue oxygenation[20,21], increased numbers of polymorphonuclear cells at surgical sites[22], and better maintenance of regional normothermia[23].

Deep vein thrombosis (DVT) and pulmonary embolism (PE) remain potentially catastrophic complications of total joint arthroplasty. Regional anesthesia has been reported to protect against DVT and PE in patients undergoing total joint arthroplasty[24,25]. However, no such tendency was evident in this study. The number of cases was small and serious results were not noted. However, the interpretation of our results was limited by the retrospective study design where we did not evaluate asymptomatic DVT and PE prospectively. Despite such limitations, it is interesting that the prevalence of symptomatic DVT and PE was not significantly different between the two groups.

Regional anesthesia reduces the need for blood transfusion in total joint arthroplasty[3,26,27]. However, several studies reported discrepant results[12,28,29]. In total hip arthroplasty, Modig and Karlstrom[30] reported that the use of epidural anesthesia, compared with GA, resulted in a preganglionic sympathetic blockade that has several beneficial effects: redistribution of blood flow away from muscle and bone to skin and subcutaneous tissues; reduction in mean arterial pressure, pulmonary arterial pressure, right atrial pressure and peripheral venous pressure; and peripheral dilatation of the arteries and veins of the extremity, resulting in less bleeding and easier attainment of hemostasis. Although TKA was generally performed under tourniquet control and most bleeding occurred after surgery, GA was associated with an increased requirement for blood transfusion in this study. The difference between the two groups might be due to postoperative bleeding during the period of remaining anesthetic effect after surgery.

This study has several limitations. First, this study involved a retrospective analysis of medical records. The decisions between GA and SA were based on the anesthesiologists' judgment according to patient's age and comorbidities. However, there might be more concerned variables such as patient characteristics, and surgical schedule. However, assuming that they could not be controlled in the real clinical situations, we treated their effects as random errors. We thought that the observed sample size was sufficiently large to cover the random errors. Although we adjusted the significantly different baseline characteristics in the statistical models to figure out the true difference in postoperative outcomes between the two groups, the interpretation has limitations due to the retrospective design. Second, data collection of complications was limited to thirty days after surgery. As some complications such as PE and DVT could occur after thirty postoperative days, we could not compare the long term differences of the two anesthetic techniques. Third, data that represent short-term clinical outcomes (pain VAS score and ROM) were not available on the medical records. Thus, short-term clinical outcomes could not be compared. Fourth, the differences in adverse events to thirty postoperative days between the two groups were very small: with less than 1% difference, we could not ascertain its clinical significance.

Conclusions

We should cautiously consider that GA may be associated with slightly increased preoperative and postoperative room times, postoperative hospital stay, transfusion and SSI rates in patients undergoing primary unilateral TKA.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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