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Comparison of general and regional anesthesia on short-term complications in patients undergoing total knee arthroplasty

A retrospective study using national health insurance service-national sample cohort

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Abstract

This retrospective study compared the mortality and short-term complications according to the choice of general anesthesia or regional anesthesia in patients who underwent a total knee arthroplasty (TKA). We searched the Korean National Health Insurance Service National Sample Cohort database to analyze data from patients who received a TKA between January 2002 and December 2015. Before comparing the general and the regional anesthesia groups, the bias was reduced by propensity score matching. After matching, the mortality and complications occurring within 30 days after a TKA were compared between the 2 groups. In the database, 6491 primary TKA cases were identified. Nine hundred forty-three patients (14.5%) had a TKA performed under general anesthesia, and 5548 (85.5%) had a TKA performed under regional anesthesia. After propensity score matching, the data of 1886 patients were analyzed, with 943 patients in each group. There was no significant difference in mortality (0.32% vs 0.00%), transfusion rate (84.52% vs 84.73%, P = .8989), and length of hospital stay (50 vs 53, P = .5391) between the general and regional anesthesia groups. Most of the complications were not significantly different, but the major complications, including myocardial infarction (1.70% vs 0.64%, P = .0414) and acute renal failure (0.85% vs 0.11%, P = .0391), were higher in the general anesthesia group than in the regional anesthesia group. Also, admission to the intensive care unit (8.48% vs 2.33%, P < .0001) and total cost (₩8067, 400 vs ₩7487, 940, P = .0002) were higher in the general anesthesia group than in the regional anesthesia group. Our study found that regional anesthesia for TKA is associated with a decrease in major complications, including myocardial infarction and acute renal failure, and medical costs.

Abbreviations: BMI = body mass index, ECS = Elixhauser Comorbidity Scores, GA = general anesthesia, ICU = intensive care unit, MI = myocardial infarction, NHIS = National Health Insurance Service, NHIS-NSC = National Health Insurance Service-National Sample Cohort, PSM = propensity score matching, PTE = pulmonary thromboembolism, RA = regional anesthesia, TKA = total knee arthroplasty.

Keywords: general anesthesia, national sample cohort, regional anesthesia, total knee arthroplasty

1. Introduction

With the increase in the aged and obese populations, the number of total knee arthroplasty (TKA) and its burden has gradually increased worldwide, including in Korea.[1–5] TKA is known as 1 of the safest and most effective surgical procedure for patients with end-stage knee arthritis.[6] Improvements in surgical techniques, patient selection, and anesthetic management have reduced mortality and complications after a TKA, but the risk of postoperative complications still exists.[7]

The type of anesthesia has been considered 1 of the risk factors for postoperative complications for a long time. Many studies have reported that regional anesthesia (RA) is more advantageous than general anesthesia (GA) in reducing mortality, length

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The data that support the findings of this study are available from a third party, but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are available from the authors upon reasonable request and with permission of the third party.;The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

This study was approved by Chung-Ang University Gwangmyeong hospital, Institutional Review Board (2210-032-048). The requirement for informed consent was waived by Chung-Ang University Gwangmyeong hospital Institutional Review Board since we used de-identified administrative claims data. All methods were performed in accordance with the relevant guidelines and regulations.

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of stay, blood transfusion, complications, and including surgical site infection and thromboembolic events.[8–11] Conversely, other researchers have reported no significant differences in blood transfusion, pain control, and complications between GA and RA.[12–14]

As the volume of TKA increases, so does the number of studies on TKA. However, most of the research is based on Western populations; however, research based on Asian populations is scarce.[15] In addition, there are many studies on the selection of the anesthesia method for TKA, but only a few studies are based on big data.[9,12]

The purpose of this study was to compare the thirty-day mortality among patients who underwent TKA under GA or RA using the Korean nationwide database of the national health insurance system called the National Health Insurance Service (NHIS) primarily. Also, this study was aimed to compare postoperative complications, transfusion and hospital stay with overall cost after TKA under GA or RA. We hypothesized that there would be significant differences in the incidences of postoperative complications according to the choice of anesthesia method.

2. Methods

This study was approved by the Institutional Review Board of Chung-Ang University Gwangmyeong hospital (2210-032-048). The requirement for informed consent was waived by the Institutional Review Board of Chung-Ang University Gwangmyeong hospital since we used de-identified administrative claims data.

This retrospective study used data from National Health Insurance Service-National Sample Cohort (NHIS-NSC). The NHIS is a single mandatory national health care institution, and almost all citizens of Korea join the NHIS. The NHIS-NSC database was produced with a systematic stratified random sampling method from 46,605,433 Korean citizens in 2002 and contains data on 1025,340 randomly selected individuals, about 2.2% of the total Korean population. The database contains each individual medical claims from January 2002 to December 2015. This database includes demographic and socio-economic characteristics, such as sex, age, region, economic level, and national health screening program data.[16] We used data from the NHIS-NSC database between 2008 and 2015.

We included all patients who underwent unilateral TKA under GA or RA in hospitals in Korea between January 2008 and December 2015. Patients were selected from the database using surgical codes for TKA (N2072 and N2077) and anesthesia codes for GA (L1211, L1212, L0101, and L0103) and RA (L1213, L1214). We excluded patients who underwent multiple operations, or staged or simultaneous bilateral operations. Also, we excluded patients with missing data. We classified the subjects into 2 groups according to the type of anesthesia, GA or RA. GA included volatile and intravenous anesthesia. RA included spinal, epidural, and combined spinal-epidural anesthesia. Demographic characteristics, such as sex, age, region, hospital type, and economic level, were recorded for all patients. The hospital type was classified as clinics, hospitals, general hospitals, or tertiary hospitals, and was determined by the number of beds. Clinics had up to 29 inpatient beds, hospitals had a minimum of 30, general hospitals had a minimum of 100 with physician specialists, and tertiary hospitals indicated general hospitals that were approved to provide most types of advanced medical care with a minimum of 20 departments. We only obtained demographic characteristics, such as height, weight, and body mass index (BMI) from 5826 individuals (89.8% of all subjects), because of the nature of the data. We employed Elixhauser Comorbidity Scores (ECS) to evaluate the patients' comorbidities.[17,18] ECS was calculated as the sum of the presence or absence of 31 comorbidity conditions, including an AIDS or HIV infection, alcohol abuse, blood loss anemia, cardiac arrhythmias, chronic pulmonary disease, coagulopathy, complicated diabetes mellitus, complicated hypertension, congestive heart failure, deficiency anemia, depression, drug abuse, fluid and electrolyte disorders, hypothyroidism, liver disease, lymphoma, metastatic cancer, obesity, other neurological disorders, paralysis, peptic ulcer disease, peripheral vascular disorders, psychoses, pulmonary circulation disorders, renal failure, rheumatoid arthritis, solid tumor without metastasis, uncomplicated hypertension, uncomplicated diabetes mellitus, valvular disease, and weight loss.

Thirty-day mortality was defined as death within 30 days of admission due to any causes. Delirium was defined as the administration of quetiapine, risperidone, or haloperidol during the hospitalization period. The transfusion rates, amounts, and types, including red blood cells, fresh frozen plasma, platelets, and whole blood, were investigated by transfusion codes. Hospital stay and total cost were also recorded. Postoperative complications, including admission to an intensive care unit (ICU), unplanned intubation, ventilator care, cardiac arrest, myocardial infarction (MI), pneumonia, pulmonary edema, acute respiratory distress syndrome, intracranial hemorrhage, stroke, pulmonary thromboembolism (PTE), other thromboembolic events, nerve injury, prosthesis failure, wound dehiscence, surgical site infection, sepsis, urinary tract infection, acute renal failure (ARF), and hepatic failure were investigated.

2.1. Statistical analysis

We matched GA and RA groups in a 1:1 ratio by propensity score matching (PSM) via the caliper matching method to minimize selection bias and the difference in demographic characteristics and comorbidities between the 2 groups. The propensity scores were calculated using age, sex, and ECS by logistic regression analysis.

The normal distribution of variables was evaluated via the Kolmogorov–Smirnov test or Shapiro–Wilk test. For pre-matching data, continuous variables were analyzed using the Wilcoxon rank-sum test, and categorical variables were compared using the Chi-square test or Fisher exact test. For postmatching, continuous variables were tested using paired *t* test or Wilcoxon signed rank-sum test, and categorical variables were compared with the McNemar test or exact McNemar test. All statistical analyses used were 2-sided, and the significance level was set at a $P < .05$. R version 3.4.1 (RStudio, Boston, MA) and SAS Enterprise Guide version 6.1 (SAS Institute Inc., Cary, NC) were used for the statistical analyses.

3. Results

We enrolled 9834 patients who underwent TKA under GA or RA from January 2008 to December 2015. Among the included patients, 3343 were excluded because of missing data, multiple operations, or staged or simultaneous bilateral operations. After exclusion, 6491 patients, who underwent unilateral primary TKA, were enrolled in this study (Fig. 1).

The annual number of TKAs increased from 2008 to 2015 according to anesthetic type. The numbers of GA were comparable from 2008 to 2015. In contrast, the numbers of spinal anesthesia were steadily increased from 2008 to 2015 (Fig. 2). The annual trend of TKAs according to the hospital type showed increased numbers of TKAs in the "hospital" setting (Fig. 3).

Before PSM, demographic characteristics, including age and ECS, showed significant differences between the GA and RA groups (Tables 1 and 2). After PSM, there were no significant differences between the 2 groups (Tables 1 and 2). Due to the limitations of the database, data for height, weight, and BMI were only available for 5826 out of 6491 people.

Thirty-day mortality, delirium, transfusion rate, length of hospital stay, and overall cost were described in Table 3. For the

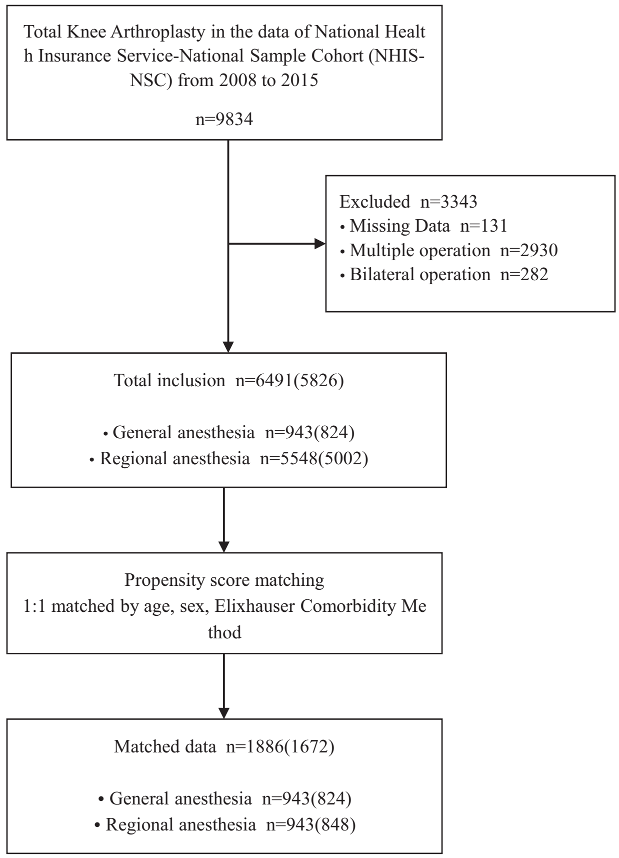

Figure 1. Flow diagram. Because of the nature of the data, demographic characteristics, such as height, weight, and body mass index (BMI) could be obtained from only 89.8% of all subjects (5826 individuals). The number of individuals for which demographic characteristics were obtained is indicated in brackets. BMI = body mass index.

pre-matching data, the 30-day mortality was not significantly different between the 2 groups. After matching, the GA group showed a higher mortality rate than the RA group, but the statistical analysis could not be performed because the mortality rate of the RA group was 0. Although the delirium rate was significantly different before PSM (P = .03), it was not significantly different after PSM. In contrast, the overall cost was higher in the GA group than in the RA group, both before and after PSM.

Postoperative complications were reported in Table 4. Though the GA group showed a higher stroke rate than the RA group before matching (P = .0208), there was no significant difference between the 2 groups after matching. Conversely, acute renal failure was not significantly different between the groups before PSM, but the GA group showed a higher acute renal failure rate compared with the RA group after PSM (P = .0391). Admission to ICU, myocardial infarction, and other thromboembolic events showed significant differences between the 2 groups before and after matching.

Figure 2 shows the number of TKA, GA, and RA by year. The number of TKA cases increased every year. The RA group also showed an increasing trend every year, while the GA group maintained a similar level every year. Figure 3 shows the number of TKAs by hospital type by year. The hospital group showed an increasing trend every year, while the other groups did not show any trends.

4. Discussion

The purpose of this study was to compare the mortality; complications, including delirium, transfusion, and hospital stay; and overall cost after a TKA under GA or RA. We found that RA reduced postoperative complications, including MI and ARF. Also, patients who underwent a TKA under RA had a lower incidence of admission to the ICU and a lower overall cost of hospitalization.

The number of TKAs has steadily increased worldwide.[1–5] In the United States, more than 680,000 TKAs were performed in 2009, and it is predicted that 3 million TKAs will be performed in 2040.[3] In Korea, more than 100,000 TKAs were performed in 2018, and it is expected to reach about 150,000 TKAs by 2030.[5] Consequently, the consumption of medical resources such as money and hospital beds due to TKAs is also increasing rapidly.

After the introduction of TKA, surgical outcomes have improved due to the advancement of anesthesia management, implants, surgical techniques, such as navigation- or robot-assist, and optimization of patient selection. However, as the number of TKAs is increasing worldwide, methods for improving surgical outcomes and reducing complications are still important

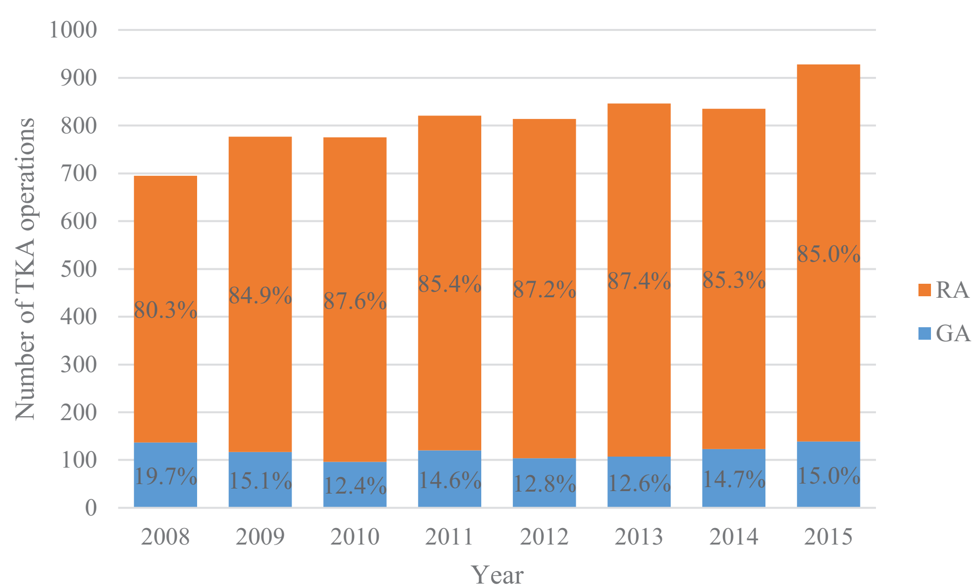

Figure 2. Annual trend of total knee arthroplasty (TKA) according to anesthetic method in Korea. Data are presented as percentages. GA, TKA under general anesthesia; RA, TKA under regional anesthesia. GA = general anesthesia, RA = regional anesthesia, TKA = total knee arthroplasty.

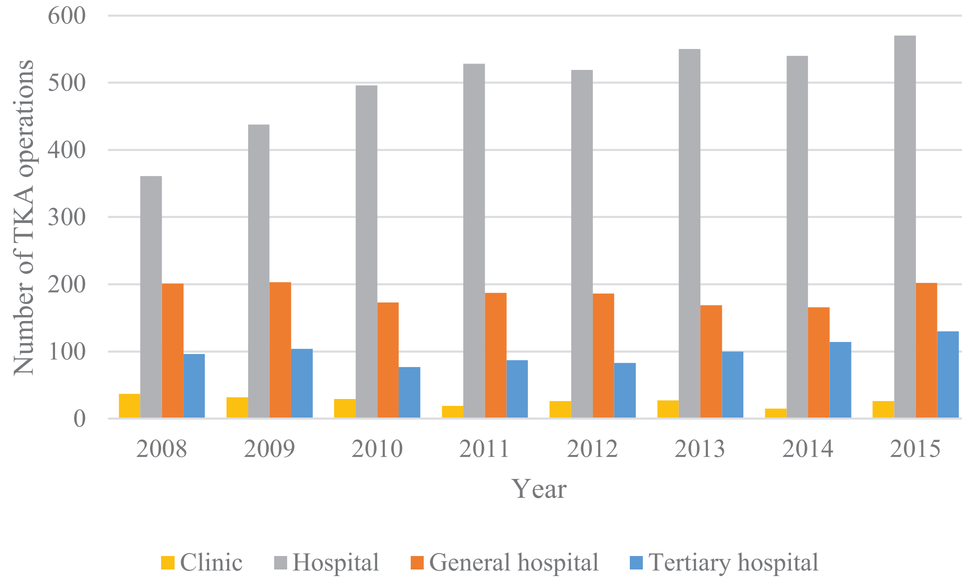

Figure 3. Annual trend of total knee arthroplasty (TKA) according to hospital type in Korea. Clinics had up to 29 inpatient beds, hospitals had a minimum of 30, general hospitals had a minimum of 100 with physician specialists, and tertiary hospitals indicated general hospitals that were approved to provide most types of advanced medical care with a minimum of 20 departments. TKA = total knee arthroplasty.

Table 1

Patient characteristics.

		Prematching			Postmatching		
	Total (n = 6491)	GA (n = 943)	RA (n = 5548)	*P* value	GA (n = 943)	RA (n = 943)	*P* value
Age (yr)	70 (65–75)	70 (64–74)	70.5 (65–75)	.0056*	70 (64–74)	70 (64–74)	.61
Sex (male/female)	846/5645	112/831	734/4814	.25	112/831	98/845	.31
Elixhauser Comorbidity Scores	7 (5–9)	7 (5–9)	6 (5–9)	.0033*	7 (5–9)	7 (5–9)	.51

Data are presented as absolute numbers or median (25th–75th percentiles).
GA = general anesthesia, RA = regional anesthesia.
* $P < .05$ between-group comparisons.

Table 2

Patient characteristics (limited data). Due to the limitations of the database, data for height, weight, and BMI were only available for 5826 out of 6491 people.

		Prematching			Postmatching		
	Total (n = 5826)	GA (n = 824)	RA (n = 5002)	*P* value	GA (n = 824)	RA (n = 848)	*P* value
Height (cm)	153 (149–157)	153 (149–157)	153 (148–157)	.6730	153 (149–157)	153 (149–157)	.82
Weight (kg)	60 (54–67)	61 (55–67)	60 (54–67)	.5157	61 (55–67)	61 (54–67)	.78
BMI (kg/cm^2)	25.8 (23.6–28.1)	25.95 (23.5–28.1)	25.7 (23.7–28.1)	.6797	25.95 (23.5–28.1)	25.8 (23.6–28.2)	.42

Data are presented as absolute numbers or median (25th–75th percentiles). *$P < .05$ between-group comparisons.
BMI = body mass index, GA = general anesthesia, RA = regional anesthesia.

issues.[1–5,7] For instance, selecting the optimal anesthesia method has been an important issue for a long time. Several studies have claimed many benefits of RA, such as reducing wound infections, transfusions, thromboembolic events, including MI and stroke, length of stay, and operation time.[8–11] However, other researchers have reported that there is no significant difference in the serious adverse events, including thromboembolic events and surgical site infections, transfusions, and length of stay between RA and GA.[12–14]

In this study, contrary to our expectations, 30-day mortality, transfusion rate, hospital stay, and most complications, including delirium, were not significantly different between the GA and RA groups. This may be due to the overall decline in the incidence of complications with advances in the management of patients receiving TKA.[19] In 1 study, a 5-year complication trend was investigated based on the TKA performed from 1990 to 2004 in the United States. Comparing the major complications in 1990 to 1994 versus 2000 to 2004, mortality (0.50% vs 0.28%) and cardiac (1.46% vs 0.91%), respiratory (1.63% vs 0.84%), peripheral vascular (0.80 % vs 0.18%), genitourinary (1.51% vs 0.64%), and device-related complications (1.40% vs 0.74%) were decreased in the later years.[20] As mentioned earlier, we believe that this decrease in complications is due to advances in patient selection, surgical techniques, and anesthesia.

However, major complications were still significantly higher in the GA group than in the RA group, including MI (1.70% vs

Table 3

Outcomes.

		Prematching			Postmatching			
	Total (n = 6491)	GA (n = 943)	RA (n = 5548)	*P* value	GA (n = 943)	RA (n = 943)	*P* value	95% CI
Mortality	12 (0.18)	3 (0.32)	9 (0.16)	0.39	3 (0.32)	0 (0.00)	.	.
Delirium	13 (0.20)	5 (0.53)	8 (0.14)	0.030*	5 (0.53)	2 (0.21)	0.45	0.038 to 2.44
Transfusion	5500 (84.73)	797 (84.52)	4703 (84.77)	0.84	797 (84.52)	799 (84.73)	0.89	0.79 to 1.30
Hospital stay (days)	52 (40 to 71)	50 (38 to 71)	52 (40 to −71)	0.25	50 (38 to 71)	53 (40 to 72)	0.54	−3.50 to 2.00
Overall cost (₩)	7664650 (5719990–10365460)	8067400 (5998720–10687850)	7547015 (5689740–10321510)	<0.0001*	8067400 (5998720–10687850)	7487940 (5713140–10199960)	0.0002*	241950–785035

Data are presented as absolute numbers, absolute numbers (percentage) or median (25th–75th percentiles).
GA = general anesthesia, RA = regional anesthesia.
* $P < .05$ between-group comparisons.

Table 4

Complications.

		Prematching			Postmatching			
	Total (n = 6491)	GA (n = 943)	RA (n = 5548)	*P* value	GA (n = 943)	RA (n = 943)	*P* value	95% CI
ICU admission	216 (3.33)	80 (8.48)	136 (2.45)	<.0001*	80 (8.48)	22 (2.33)	<.0001*	0.17–0.44
Unplanned intubation	3 (0.05)	0 (0.00)	3 (0.05)	1.0000	0 (0.00)	0 (0.00)	.	.
Ventilator care	0 (0.00)	0 (0.00)	0 (0.00)	.	0 (0.00)	0 (0.00)	.	.
Cardiac arrest	1 (0.02)	0 (0.00)	1 (0.02)	1.0000	0 (0.00)	0 (0.00)	.	.
Myocardial infarction	55 (0.85)	16 (1.70)	39 (0.70)	.0021*	16 (1.70)	6 (0.64)	.041*	0.095–0.96
Pneumonia	52 (0.80)	11 (1.17)	41 (0.74)	.17	11 (1.17)	6 (0.64)	.30	0.13–1.60
Pulmonary edema	45 (0.69)	7 (0.74)	38 (0.68)	.84	7 (0.74)	4 (0.42)	.55	0.12–2.25
Acute respiratory distress syndrome	8 (0.12)	0 (0.00)	8 (0.14)	0.61	0 (0.00)	0 (0.00)	.	.
Intracranial hemorrhage	8 (0.12)	2 (0.21)	6 (0.11)	.33	2 (0.21)	0 (0.00)	.	.
Stroke	113 (1.74)	25 (2.65)	88 (1.59)	.021*	25 (2.65)	16 (1.70)	.16	0.34–1.19
Pulmonary thromboembolism	19 (0.29)	4 (0.42)	15 (0.27)	.51	4 (0.42)	0 (0.00)	.	.
Other Thromboembolic event	246 (3.79)	17 (1.80)	229 (4.13)	.0005*	17 (1.80)	48 (5.09)	.0001*	1.62–4.91
Nerve injury	1 (0.02)	0 (0.00)	1 (0.02)	1.00	0 (0.00)	0 (0.00)	.	.
Prosthesis failure	16 (0.25)	3 (0.32)	13 (0.23)	.72	3 (0.32)	2 (0.21)	1.00	0.056–5.82
Wound dehiscence	35 (0.54)	6 (0.64)	29 (0.52)	.66	6 (0.64)	5 (0.53)	1.00	0.20–3.28
site infection	199 (3.07)	29 (3.08)	170 (3.06)	.98	29 (3.08)	19 (2.01)	.15	0.37–1.17
Sepsis	4 (0.06)	0 (0.00)	4 (0.07)	1.00	0 (0.00)	1 (0.11)	.	.
Urinary tract infection	261 (4.02)	35 (3.71)	226 (4.07)	.60	35 (3.71)	37 (3.92)	.81	0.66–1.72
Acute renal failure	28 (0.43)	8 (0.85)	20 (0.36)	.053	8 (0.85)	1 (0.11)	.039*	0.0028–0.93
Hepatic failure	7 (0.11)	0 (0.00)	7 (0.13)	.60	0 (0.00)	2 (0.21)	.	.

Data are presented as absolute numbers, absolute numbers (percentage) or median (25th–75th percentiles).
GA = general anesthesia, ICU = intensive care unit, RA = regional anesthesia.
* $P < .05$ between-group comparisons.

0.64%, $P = .0414$) and ARF (0.85% vs 0.11%, $P = .0391$). The proposed hypothesis is that RA could avoid tracheal intubation and mechanical ventilation and reduce inflammation and sympathetic stimulation.[21,22] Also, ICU admission was significantly higher in the GA group than in the RA group in the current study (8.48% vs 2.33%, $P < .0001$). We assumed that the higher incidence of MI and ARF in the GA group may be 1 reason for the higher admission to the ICU in the GA group since MI and ARF are the main causes of ICU admission. Moreover, the GA group showed a higher hospital cost (₩8,067,400 vs ₩7,487,940, $P = .0002$) than the RA group in this study. Differences in the complication rate and admission to the ICU between the 2 groups could be reasons for the difference in hospital costs.

Other thromboembolic events, except for stroke, MI, and PTE, were higher in the RA group. However, in all thromboembolic events, including stroke, MI, and PTE, the 2 groups showed a similar ratio. We think these results were obtained by separating stroke, MI, PTE, and other thromboembolic events.

In this study, most complications, including mortality, delirium, transfusion, and did not show significant differences between the 2 groups. Previous studies have shown that RA is beneficial in reducing most complications by reducing venous stasis, inflammation, and sympathetic activation.[8–11] One cause of these differences would be the improvement of GA. Propofol and remifentanil, the leading drugs used for GA, could be appropriately adjusted according to stimuli with target-controlled infusions, effectively reducing sympathetic activation and inflammatory response during GA. Other causes include advances in surgical techniques, such as precise surgical planning through preoperative imaging, the assistance of navigation-or robots, and the use of a tourniquet. Also, prophylactic antibiotic therapy effectively reduces postoperative infection. Advances in patient management have reduced overall complications, and the gap between GA and RA has narrowed.

Like in other studies, the number of TKA cases gradually increased in this study.[1–5] The annual number of TKAs with RA gradually increased, but the annual number of TKAs with GA remained constant (Fig. 2). We assumed that since previous studies showed that RA was more advantageous than GA, clinicians preferred RA.[8–11] In contrast, a gradual increase in TKAs in the hospital group was observed; however, the annual number of TKAs in the advanced general hospital group and the general hospital group remained constant (Fig. 3). Similar decentralization has also been reported in another study.[20] These results are interesting because there have been studies that show that larger hospitals have better TKA outcomes.[23] We speculated that this trend might be associated with a decrease in the overall complications of TKA. Since severe complications were also reduced, TKA could be sufficiently conducted in the hospital group. Further studies are needed on the relationship between types of hospitals and surgical outcomes.

The patient selection for RA was also interesting. In the pre-matching data of Tables 1 and 2, the ECS of the GA group was higher. There was no significant difference in BMI between the 2 groups, and the mean age of the RA group was higher. Although PSM eliminates these differences during the analysis, pre-matching data suggest that anesthesiologists likely focused on comorbidities than BMI and age during patient selection for RA.

The present study had several limitations. First, this study is a retrospective study using NHIS-NSC database that the conclusion shows limitations to be generalized. Although randomized controlled study might provide higher evidence than retrospective study, it is not easy to control anesthetic method prospectively in a real world. In this aspect, this study has not only limitation but also strength which included large number of patients. Second, we used the NHIS-NSC database, which is intended for billing purposes, and may not be suitable for studying mortality or complications. Therefore, we could not analyze the surgical results, such as postoperative pain or joint mobility, which are not provided in the database. Also, important information, such as operation time, anesthesia time, and readmission rate, could not be obtained. Moreover, some data, such as height and weight, were not available for all patients. Third, we compared only short-term mortality and complications. We suggested that short-term mortality and complications could reflect the effects of anesthesia. Fourth, there may be bias because the diagnosis or prescription was defined based on the NHIS code. Each center may have different criteria for diagnosing or prescribing. Fifth, although preferred anesthesia methods and surgical protocols may differ from center to center, they might be ignored. To reduce this weakness, we removed ambiguous data and used statistical methods, such as the PSM method, but this data is still different from data designed for research.

In conclusion, the choice of anesthesia technique did not affect mortality, transfusion rates, or length of hospital stay in patients receiving TKA. However, major complications, including MI and ARF, and admission to ICU and total cost were higher in the GA group than in the RA group. Therefore, RA would be advantageous for TKA in patients with comorbidities with a high risk of MI or ARF.

Author contributions

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Validation: EunJin Ahn.
Visualization: EunJin Ahn.
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Writing – review & editing: Min Kyoung Kim, EunJin Ahn, YongHun Jung.

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