


# Risk factors of postoperative complications following total knee arthroplasty in Korea

## A nationwide retrospective cohort study

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### Abstract

**Background:** The number of patients undergoing total knee arthroplasty (TKA) is gradually increasing and there is also increase in postoperative complications. The patient's demographic, socio-economic factors, hospital and clinical factors are all factors that can influence postoperative complications. The purpose of this study was to determine the risk factors associated with complications following TKA in a large national cohort.

**Methods:** Among patients diagnosed with primary knee arthrosis, a total of 560,954 patients older than 50 years who underwent TKA from January 1, 2005 to December 31, 2018 were included in the study. The risk of postoperative complications (surgical site infection, sepsis, cardiovascular complications, respiratory complications, pulmonary embolism, stroke, acute renal failure, periprosthetic joint infection, and periprosthetic fracture) were assessed with eight independent variables: gender, age, place of residence, household income, hospital bed size, procedure type (unilateral or bilateral, primary or revision TKA), length of stay (LOS), use of transfusion. Multivariable Cox Proportional Hazard model analysis was used. The significant predictors for complications ( $P < .05$ ) were as follows.

**Results:** Surgical site infection: male, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Sepsis: male, household income, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Cardiovascular complications: male, age, household income, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Respiratory complications: male, household income, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Pulmonary embolism: male, household income, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Stroke: male, age, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Acute renal failure: male, household income, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Periprosthetic joint infection: male, household income, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion. Periprosthetic fracture: male, procedure type (bilateral, revision), LOS ( $\geq 35$  days), transfusion.

**Conclusion:** In summary, male, procedure type (bilateral, revision), LOS ( $\geq 35$  days), and use of transfusion were shown to be risk factors of postoperative complications following TKA.

**Abbreviations:** ARF = Acute renal failure, BTKA = bilateral TKA, HR = hazard ratio, LOS = length of stay, PJI = Periprosthetic joint infection, SES = socioeconomic status, SSI = Surgical site infection, THA = total hip arthroplasty, TKA = Total knee arthroplasty, UTKA = unilateral TKA.

**Keywords:** big data, knee, nationwide analysis, postoperative complication, total knee arthroplasty

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## 1. Introduction

Total knee arthroplasty (TKA) is a treatment that is performed at the end stage of degenerative knee osteoarthritis. It can relieve pain, recover joint function, and improve the quality of life.<sup>[1]</sup> More than 600,000 procedures are performed per year in the United States, and it is estimated to continue to increase to 3.5 million procedures in 2030.<sup>[2]</sup> The trend of South Korea also increased more than 5 times from 14,887 cases in 2001 to 75,434 cases in 2010.<sup>[3]</sup>

Nonetheless, TKA may be associated with mortality and life-threatening complications.<sup>[4,5]</sup> With the increasing incidence of complications, the rate of readmission was also increasing in recent years.<sup>[6]</sup> The increase in medical costs due to postoperative complications of TKA eventually put expense burden to patients and national health care institutions.<sup>[7]</sup> These are important to both the clinician and the patient, as they can account for resource use as well as costs, and delayed return to normal activity and work.<sup>[8]</sup>

Therefore, it is necessary to make an effort to reduce postoperative complications, and at the same time, it is necessary to determine what risk factors exist. These efforts allow the medical community to optimize the resources used for TKA.

According to Kurz et al,<sup>[9]</sup> the most frequently reported major reasons for readmission in TKA were surgical and medical complications (Wound infection [6.2%], deep infection [4.5%], atrial fibrillation [3.9%], lower extremity cellulitis and abscess [3.0%] or pulmonary embolism [2.6%]). They found that patient factors (e.g., age, gender, socioeconomic status), hospital factors (e.g., bed size, type of hospital), and clinical factor (e.g., length of stay, use of transfusion) all had an influence on these outcomes.

Few studies have comprehensively examined patient, hospital, and clinical factors, but they were mainly about readmission and the hospital costs or mortality.<sup>[9,10]</sup> To the best of our knowledge, previous studies of patient, hospital, and clinical factors associated with postoperative complications as comprehensively as in this study have not been reported.

The purpose of this study was to determine the risk factors associated with complications following TKA in a large national cohort.

## 2. Methods

This study is a retrospective observational cohort study using large nationwide data provided by the National Health Insurance Service (National Health Insurance Service-HealthScreening; NHIS-HealS) with the approval of the institutional review committee of the Ethics Committee of Ilsan Hospital.

In recent studies, it was reported that TKA is a good treatment option for osteoarthritis of the knee in an extreme age group for patients <55 years old or >90 years old.<sup>[11,12]</sup> According to Williams et al, TKA was performed the most in adults aged 45 years and older in the United States in 2010, and adults aged 45 years and older accounted for 98.1% of surgeries. Those aged 65 and older had higher rates of TKA than those aged 45 to 64 in both 2000 and 2010 (58.0 and 92.1 per 10,000, respectively for those aged 65 and older compared with 12.7 and 37.8 per 10,000 for those aged 45–64).<sup>[13]</sup> Based on the results of the previous study, Among patients diagnosed with primary knee arthrosis (diagnostic codes: M170, M171), patients older than 50 years who had been charged for hospitalization, and underwent TKA from January 1, 2005 to December 31, 2018 were included in the study. Records with procedural codes of primary TKA (N0712,

N2072, and N2077) and revision TKA (N1712, N3712, and N3717) were selected. Patients who underwent surgery due to traumatic osteoarthritis, secondary osteoarthritis, and pyogenic arthritis, had previously undergone TKA or total hip arthroplasty (THA), and had undergone high tibial osteotomy or unicompartmental knee arthroplasty on the same knee were excluded.

The potential risk factors for complications that we evaluated included gender, age (50–59, 60–69, 70–79, and ≥80 years), it is already known that age is related to complications, and it has been reported that complications increase at a certain rate as the patient's age increases by 10 years.<sup>[14,15]</sup> Therefore, we set the age grouping range to 10 years, place of residence (Seoul, metropolitan city, city, rural), household income (medical benefits, 1st, 2nd, 3rd, 4th quartile), in this study, household income was used as an indicator of socioeconomic status (SES). It is one of the most widely accepted methods to quantify SES and has been found to accurately reflect SES-related health disparities.<sup>[16]</sup> Patients were assigned to the income percentile and quartiles excluding medical benefits, procedure type (unilateral or bilateral, primary or revision TKA), bed size (small [30–99], medium [100–499], large [≥500]), length of stay (LOS) (<15, 15–24, 25–34, ≥35 days) and use of transfusion. We considered the gender, age, place of residence, and household income as patient factors, it was assumed that the socioeconomic status and place of residence would have an effect on the patient's preoperative walking ability, capacity for daily activities, and support necessary for these activities, which would have a close causal relationship to the postoperative outcome, bed size as hospital factor, and procedure type, LOS, and use of transfusion as clinical factors.

We evaluated the frequency and hazard ratio (HR) of postoperative complications following TKA. These were major medical complications and surgical complications. Investigated postoperative complications are as follows.

1. Surgical site infection (SSI),
2. Sepsis,
3. Cardiovascular complications (acute coronary syndrome, heart failure),
4. Respiratory complications (pneumonia, respiratory failure),
5. Pulmonary embolism,
6. Stroke (cerebral infarction or hemorrhage),
7. Acute renal failure (ARF),
8. Periprosthetic joint infection (PJI),
9. Periprosthetic fracture.

These complications were chosen from among the diagnoses that were the cause of readmission following TKA reported in a recent publication and unlike minor complications, they were selected due to their major effect on health.<sup>[17]</sup>

For all analyses, SAS 9.4 (SAS Inc, Cary, NC) was used. Multivariable Cox Proportional Hazard model analysis was used for eight independent variables of postoperative complications. In the case of complications and hospital-related variables, there were no missing data due to the nature of the claim data and cases in which patient-related variables were missing due to information errors were extremely rare and these were excluded. HR and 95% confidence interval (CI) are presented. The level of significance was maintained with a *P* value < .05.

## 3. Results

From 2005 to 2018, a total of 560,954 patients who underwent TKA were found. Table 1 shows the total number of cases of TKA

**Table 1**  
Annual number of total knee arthroplasty in Korea.

| Year         | Patients No.   | Male          |              | Female         |              |
|--------------|----------------|---------------|--------------|----------------|--------------|
|              |                | No.           | %            | No.            | %            |
| 2005         | 13,880         | 1,267         | 9.13         | 12,613         | 90.87        |
| 2006         | 20,067         | 1,936         | 9.65         | 18,131         | 90.35        |
| 2007         | 25,916         | 2,548         | 9.83         | 23,368         | 90.17        |
| 2008         | 29,980         | 3,106         | 10.36        | 26,874         | 89.64        |
| 2009         | 34,933         | 3,805         | 10.89        | 31,128         | 89.11        |
| 2010         | 39,007         | 4,493         | 11.52        | 34,514         | 88.48        |
| 2011         | 40,291         | 4,776         | 11.85        | 35,515         | 88.15        |
| 2012         | 43,171         | 5,214         | 12.08        | 37,957         | 87.92        |
| 2013         | 43,298         | 5,782         | 13.35        | 37,516         | 86.65        |
| 2014         | 44,045         | 5,925         | 13.45        | 38,120         | 86.55        |
| 2015         | 49,408         | 6,885         | 13.93        | 42,523         | 86.07        |
| 2016         | 57,580         | 8,335         | 14.48        | 49,245         | 85.52        |
| 2017         | 58,820         | 8,930         | 15.18        | 49,890         | 84.82        |
| 2018         | 60,558         | 9,659         | 15.95        | 50,899         | 84.05        |
| <b>Total</b> | <b>560,954</b> | <b>72,661</b> | <b>12.95</b> | <b>488,293</b> | <b>87.05</b> |

per year according to gender. The number of patients undergoing TKA has increased over the years in data, from 13,880 cases in 2005 to 60,558 cases in 2018. Among patients who underwent TKA, 13% were male and 87% were female.

The results of multivariate analyses for each complication are as follows.

### 3.1. Risk factors for surgical site infection

After TKA, infection occurred in 12,474 cases. The HR increased in male (HR 1.255;  $P < .0001$ ). The risk increased in the bilateral TKA (BTKA) group, longer hospital stays, and transfusion group (HR 1.354;  $P < .0001$ , HR 1.451 ( $\geq 35$  days);  $P < .0001$ , HR 1.735;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 17.815 ( $P < .0001$ ) (Table 2).

### 3.2. Risk factors for sepsis

Sepsis occurred in 10,139 cases after TKA. The risk increased in male gender (HR 1.379;  $P < .0001$ ). It was found that the risk of sepsis decreased in the highest income group (HR 0.802;  $P < .0001$ , 4th quartile). The HR increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.505;  $P < .001$ , HR = 1.476 ( $\geq 35$  days);  $P < .0001$ , HR 1.226;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 28.884 ( $P < .0001$ ) (Table 3).

### 3.3. Risk factors for cardiovascular complications

Cardiovascular complications after TKA replacement was shown in 37,467 cases. Compared to female, the risk of male increased (HR 1.119;  $P < .0001$ ). HR tended to increase with age (60–69: HR 1.040;  $P = .061$ , 70–79: HR 1.225;  $P < .001$ ,  $\geq 80$ : HR 1.449;  $P < .0001$ ). In the case of residence, the Seoul area had increased risk compared to metropolitan cities and cities, whereas the risk of rural region was higher than that of Seoul. It was found that the risk of cardiac complications decreased in the highest income group (HR 0.755;  $P < .0001$ , 4th quartile). The risk increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.076;  $P = .002$ , HR 1.090 ( $\geq 35$  days);  $P < .0001$ , HR 1.520;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 4.494 ( $P < .0001$ ) (Table 4).

**Table 2**  
Cox proportional hazard models of surgical site infection by variables.

| Multivariable analysis |        |               |        |
|------------------------|--------|---------------|--------|
| Variables              | HR     | 95% CI        | P      |
| Gender                 |        |               |        |
| Male                   | 1.255  | 1.189–1.324   | <.0001 |
| Female                 | 1.000  |               |        |
| Age                    |        |               |        |
| 50–9                   | 1.000  |               |        |
| 60–69                  | 0.772  | 0.728–0.818   | <.0001 |
| 70–79                  | 0.664  | 0.626–0.704   | <.0001 |
| $\geq 80$              | 0.660  | 0.601–0.725   | <.0001 |
| Residence              |        |               |        |
| Seoul                  | 1.000  |               |        |
| Metropolitan city      | 1.019  | 0.961–1.080   | .5289  |
| City                   | 0.999  | 0.948–1.052   | .9679  |
| Rural                  | 1.076  | 1.015–1.141   | .0133  |
| Income                 |        |               |        |
| Medical benefits       | 1.000  |               |        |
| 1st quartile           | 1.156  | 1.078–1.239   | <.0001 |
| 2nd quartile           | 1.146  | 1.068–1.230   | .0002  |
| 3rd quartile           | 1.120  | 1.049–1.196   | .0007  |
| 4th quartile           | 1.079  | 1.015–1.147   | .0153  |
| Procedure type         |        |               |        |
| Unilateral             | 1.000  |               |        |
| Bilateral              | 1.354  | 1.259–1.457   | <.0001 |
| Other                  | 0.906  | 0.727–1.130   | .3822  |
| Primary                | 1.000  |               |        |
| Revision               | 17.815 | 17.080–18.582 | <.0001 |
| Bed size               |        |               |        |
| Large ( $\geq 500$ )   | 1.140  | 1.054–1.233   | .001   |
| Medium (100–499)       | 0.853  | 0.789–0.923   | <.0001 |
| Small (30–99)          | 1.000  |               |        |
| Length of stay (D)     |        |               |        |
| <15                    | 1.000  |               |        |
| 15–24                  | 1.237  | 1.151–1.329   | <.0001 |
| 25–34                  | 1.307  | 1.212–1.409   | <.0001 |
| $\geq 35$              | 1.451  | 1.348–1.562   | <.0001 |
| Transfusion            |        |               |        |
| No                     | 1.000  |               |        |
| Yes                    | 1.735  | 1.669–1.803   | <.0001 |

### 3.4. Risk factors for respiratory complications

After TKA, respiratory complications occurred in 25,477 cases. In respiratory disease, there was also a difference in gender. The risk of male increased compared to that of female (HR = 1.197;  $P < .0001$ ). In the terms of residence, the HR pattern was similar to that of cardiovascular complications. It was found that the risk of respiratory complications decreased in the highest income group (HR 0.693;  $P < .0001$ , 4th quartile). The risk increased in the bilateral TKA group, longer hospital stays, and transfusion group (HR 1.110;  $P < .0001$ , HR 1.173 ( $\geq 35$  days);  $P < .0001$ , HR 1.562;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 6.846 ( $P < .0001$ ) (Table 5).

### 3.5. Risk factors for pulmonary embolism

After TKA, pulmonary embolism occurred in 12,029 cases. Looking at the risk factors for pulmonary embolism, there was a difference in gender (HR 1.354;  $P < .0001$ , male), and the HR decreased in older patients. It was found that the risk of developing pulmonary embolism decreased in the highest income

**Table 3**  
Cox proportional hazard models of sepsis by variables.

| Multivariable analysis |        |               |        |
|------------------------|--------|---------------|--------|
| Variables              | HR     | 95% CI        | P      |
| Gender                 |        |               |        |
| Male                   | 1.379  | 1.302–1.462   | <.0001 |
| Female                 | 1.000  |               |        |
| Age                    |        |               |        |
| 50–59                  | 1.000  |               |        |
| 60–69                  | 0.785  | 0.737–0.836   | <.0001 |
| 70–79                  | 0.662  | 0.621–0.706   | <.0001 |
| ≥80                    | 0.697  | 0.630–0.771   | <.0001 |
| Residence              |        |               |        |
| Seoul                  | 1.000  |               |        |
| Metropolitan city      | 1.019  | 0.956–1.085   | .5677  |
| City                   | 0.924  | 0.873–0.978   | .0062  |
| Rural                  | 1.011  | 0.948–1.078   | .7464  |
| Income                 |        |               |        |
| Medical benefits       | 1.000  |               |        |
| 1st quartile           | 1.007  | 0.936–1.082   | .8604  |
| 2nd quartile           | 0.998  | 0.927–1.074   | .9580  |
| 3rd quartile           | 0.883  | 0.824–0.946   | .0004  |
| 4th quartile           | 0.802  | 0.752–0.855   | <.0001 |
| Procedure type         |        |               |        |
| Unilateral             | 1.000  |               |        |
| Bilateral              | 1.505  | 1.392–1.627   | <.0001 |
| Other                  | 1.098  | 0.875–1.377   | .4204  |
| Primary                | 1.000  |               |        |
| Revision               | 28.884 | 27.664–30.157 | <.0001 |
| Bed size               |        |               |        |
| Large (≥500)           | 1.320  | 1.205–1.447   | <.0001 |
| Medium (100–499)       | 0.940  | 0.858–1.030   | .183   |
| Small (30–99)          | 1.000  |               |        |
| Length of stay (D)     |        |               |        |
| <15                    | 1.000  |               |        |
| 15–24                  | 1.277  | 1.172–1.386   | <.0001 |
| 25–34                  | 1.368  | 1.256–1.491   | <.0001 |
| ≥35                    | 1.476  | 1.357–1.605   | <.0001 |
| Transfusion            |        |               |        |
| No                     | 1.000  |               |        |
| Yes                    | 1.226  | 1.172–1.283   | <.0001 |

group compared to the lower income group (HR 0.803;  $P < .0001$ , 4th quartile). The risk increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.632;  $P < .0001$ , HR 1.460 (≥35 days);  $P < .0001$ , HR 1.288;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 29.661 ( $P < .0001$ ) (Table 6).

### 3.6. Risk factors for stroke

After TKA, 75,229 cases of stroke were occurred, indicating that the incidence was higher than that of other complications. The risk of male increased compared to that of female (HR 1.261;  $P < .0001$ ). The risk increased with age. Compared to those in their 50s, the HR of stroke was 1.343 in the 60s, 1.818 in the 70s, and 2.282 in the 80s (all  $P < .0001$ ). In the case of residence, the risk increased in rural region compared to Seoul (HR 1.208;  $P < .0001$ ). The risk increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.108;  $P < .0001$ , HR 1.146 (≥35 days);  $P < .0001$ , HR 1.465;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 2.552 ( $P < .0001$ ) (Table 7).

**Table 4**  
Cox proportional hazard models of cardiovascular complication by variables.

| Multivariable analysis |       |             |        |
|------------------------|-------|-------------|--------|
| Variables              | HR    | 95% CI      | P      |
| Gender                 |       |             |        |
| Male                   | 1.119 | 1.084–1.155 | <.0001 |
| Female                 | 1.000 |             |        |
| Age                    |       |             |        |
| 50–59                  | 1.000 |             |        |
| 60–69                  | 1.040 | 0.998–1.083 | .061   |
| 70–79                  | 1.225 | 1.177–1.276 | <.0001 |
| ≥80                    | 1.449 | 1.373–1.529 | <.0001 |
| Residence              |       |             |        |
| Seoul                  | 1.000 |             |        |
| Metropolitan city      | 0.833 | 0.805–0.862 | <.0001 |
| City                   | 0.945 | 0.918–0.973 | .000   |
| Rural                  | 1.033 | 1.000–1.067 | .052   |
| Income                 |       |             |        |
| Medical benefits       | 1.000 |             |        |
| 1st quartile           | 1.062 | 1.023–1.102 | .002   |
| 2nd quartile           | 1.079 | 1.039–1.121 | <.0001 |
| 3rd quartile           | 0.895 | 0.864–0.928 | <.0001 |
| 4th quartile           | 0.755 | 0.730–0.780 | <.0001 |
| Procedure type         |       |             |        |
| Unilateral             | 1.000 |             |        |
| Bilateral              | 1.076 | 1.027–1.128 | .002   |
| Other                  | 0.886 | 0.781–1.006 | .063   |
| Primary                | 1.000 |             |        |
| Revision               | 4.494 | 4.329–4.666 | <.0001 |
| Bed size               |       |             |        |
| Large (≥500)           | 1.035 | 0.988–1.084 | .150   |
| Medium (100–499)       | 0.923 | 0.881–0.966 | .0006  |
| Small (30–99)          | 1.000 |             |        |
| Length of stay (D)     |       |             |        |
| <15                    | 1.000 |             |        |
| 15–24                  | 0.993 | 0.957–1.031 | .722   |
| 25–34                  | 1.006 | 0.967–1.046 | .775   |
| ≥35                    | 1.090 | 1.048–1.134 | <.0001 |
| Transfusion            |       |             |        |
| No                     | 1.000 |             |        |
| Yes                    | 1.520 | 1.486–1.555 | <.0001 |

### 3.7. Risk factors for acute renal failure

There were 10,854 cases of ARF after TKA. There was a difference in gender (male, HR 1.324;  $P < .0001$ ). In terms of income, higher income groups tended to have lower risk of ARF (HR 0.814;  $P < .0001$ , 4th quartile). The risk increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.531;  $P < .0001$ , HR 1.408 (≥35 days);  $P < .0001$ , HR 1.338;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 25.357 ( $P < .0001$ ) (Table 8).

### 3.8. Risk factors for periprosthetic joint infection

PJI is one of major orthopaedic complications after TKA and there were 9951 cases. There was a statistically significant increase in risk in male (HR 1.409;  $P < .001$ ). HR tended to increase as the patient's age group decreased (60–69: HR 0.774;  $P < .0001$ , 70–79: HR 0.633;  $P < .001$ , ≥80: HR 0.635;  $P < .0001$ ). It was found that the risk of PJI decreased in the group with the highest income (HR 0.788;  $P < .0001$ , 4th

**Table 5**  
Cox proportional hazard models of respiratory complication by variables.

| Multivariable analysis |       |             |        |
|------------------------|-------|-------------|--------|
| Variables              | HR    | 95% CI      | P      |
| Gender                 |       |             |        |
| Male                   | 1.197 | 1.152–1.243 | <.0001 |
| Female                 | 1.000 |             |        |
| Age                    |       |             |        |
| 50–59                  | 1.000 |             |        |
| 60–69                  | 0.939 | 0.897–0.982 | .007   |
| 70–79                  | 1.005 | 0.960–1.052 | .843   |
| ≥80                    | 1.136 | 1.065–1.212 | .000   |
| Residence              |       |             |        |
| Seoul                  | 1.000 |             |        |
| Metropolitan city      | 0.878 | 0.842–0.916 | <.0001 |
| City                   | 0.991 | 0.956–1.028 | .627   |
| Rural                  | 1.188 | 1.142–1.237 | <.0001 |
| Income                 |       |             |        |
| Medical benefits       | 1.000 |             |        |
| 1st quartile           | 1.026 | 0.981–1.074 | .258   |
| 2nd quartile           | 1.054 | 1.007–1.103 | .024   |
| 3rd quartile           | 0.892 | 0.854–0.931 | <.0001 |
| 4th quartile           | 0.693 | 0.666–0.722 | <.0001 |
| Procedure type         |       |             |        |
| Unilateral             | 1.000 |             |        |
| Bilateral              | 1.110 | 1.050–1.174 | .000   |
| Other                  | 0.823 | 0.700–0.967 | .018   |
| Primary                | 1.000 |             |        |
| Revision               | 6.846 | 6.586–7.117 | <.0001 |
| Bed size               |       |             |        |
| Large (≥500)           | 1.102 | 1.041–1.167 | .001   |
| Medium (100–499)       | 0.972 | 0.919–1.028 | .3255  |
| Small (30–99)          | 1.000 |             |        |
| Length of stay (D)     |       |             |        |
| <15                    | 1.000 |             |        |
| 15–24                  | 1.001 | 0.956–1.048 | .964   |
| 25–34                  | 1.064 | 1.014–1.116 | .012   |
| ≥35                    | 1.173 | 1.118–1.231 | <.0001 |
| Transfusion            |       |             |        |
| No                     | 1.000 |             |        |
| Yes                    | 1.562 | 1.520–1.606 | <.0001 |

quartile). The risk was higher in general hospitals than hospitals and clinics (HR 1.251;  $P < .0001$ ). The risk increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.551;  $P < .0001$ , HR 1.439 (≥35 days);  $P < .0001$ , HR 1.155;  $P < .0001$ , respectively). In the case of revision surgery, the HR was 33.158 ( $P < .0001$ ) (Table 9).

### 3.9. Risk factors for periprosthetic fracture

Periprosthetic fracture is also one of major orthopaedic complications after TKA and there were 17,378 cases. The risk increased in male patients (HR 1.090;  $P = .000$ ) and young patients (60–69: HR 0.796;  $P < .0001$ , 70–79: HR 0.701;  $P < .001$ , ≥80: HR 0.767;  $P < .0001$ ). This may be explained in relation to the patient's activity. In terms of residential areas, the risk of metropolitan cities, cities, and rural region increased compared to Seoul (HR 1.054;  $P = .038$ , HR 1.031;  $P = .174$ , HR 1.073;  $P = .006$ , respectively). The risk increased in the BTKA group, longer hospital stays, and transfusion group (HR 1.321;  $P < .0001$ , HR 1.517 (≥35 days);  $P < .0001$ , HR 2.222;

**Table 6**  
Cox proportional hazard models of pulmonary embolism by variables.

| Multivariable analysis |        |               |        |
|------------------------|--------|---------------|--------|
| Variables              | HR     | 95% CI        | P      |
| Gender                 |        |               |        |
| Male                   | 1.354  | 1.284–1.428   | <.0001 |
| Female                 | 1.000  |               |        |
| Age                    |        |               |        |
| 50–59                  | 1.000  |               |        |
| 60–69                  | 0.767  | 0.724–0.812   | <.0001 |
| 70–79                  | 0.669  | 0.631–0.709   | <.0001 |
| ≥80                    | 0.709  | 0.647–0.777   | <.0001 |
| Residence              |        |               |        |
| Seoul                  | 1.000  |               |        |
| Metropolitan city      | 1.026  | 0.968–1.087   | .394   |
| City                   | 0.930  | 0.883–0.980   | .007   |
| Rural                  | 1.019  | 0.960–1.081   | .536   |
| Income                 |        |               |        |
| Medical benefits       | 1.000  |               |        |
| 1st quartile           | 1.044  | 0.977–1.115   | .205   |
| 2nd quartile           | 1.046  | 0.978–1.119   | .191   |
| 3rd quartile           | 0.936  | 0.879–0.997   | .040   |
| 4th quartile           | 0.803  | 0.757–0.852   | <.0001 |
| Procedure type         |        |               |        |
| Unilateral             | 1.000  |               |        |
| Bilateral              | 1.632  | 1.524–1.749   | <.0001 |
| Other                  | 1.277  | 1.058–1.543   | .011   |
| Primary                | 1.000  |               |        |
| Revision               | 29.661 | 28.515–30.854 | <.0001 |
| Bed size               |        |               |        |
| Large (≥500)           | 1.260  | 1.158–1.370   | <.0001 |
| Medium (100–499)       | 0.925  | 0.851–1.006   | .0688  |
| Small (30–99)          | 1.000  |               |        |
| Length of stay (D)     |        |               |        |
| <15                    | 1.000  |               |        |
| 15–24                  | 1.224  | 1.135–1.320   | <.0001 |
| 25–34                  | 1.295  | 1.197–1.401   | <.0001 |
| ≥35                    | 1.460  | 1.353–1.577   | <.0001 |
| Transfusion            |        |               |        |
| No                     | 1.000  |               |        |
| Yes                    | 1.288  | 1.236–1.342   | <.0001 |

$P < .0001$ , respectively). In the case of revision surgery, the HR was 13.774 ( $P < .0001$ ) (Table 10).

## 4. Discussion

This study was a long-term analysis from 2005 to 2018, and it was possible to find out the difference in the risk of complications by patient, hospital, and clinical factors.

We found that male is a significant risk factor in all analyzed complications. Complications of patients after total joint arthroplasty have been well reported, but in previous studies, complications were not stratified according to the patient's gender.<sup>[18]</sup> Several recent studies have shown that male gender is associated with an increased risk of complications such as surgical site infection, sepsis, and myocardial infarction, suggesting that gender may play an important role in the rate of complications after TKA.<sup>[18,19]</sup> Although limited to surgical site infections, men were more likely to have smoking history, diabetes, obesity, long surgery times, and American Society of Anesthesiologists class >2, which contributed to the higher

**Table 7**  
Cox proportional hazard models of stroke by variables.

| Multivariable analysis |       |             |        |
|------------------------|-------|-------------|--------|
| Variables              | HR    | 95% CI      | P      |
| Gender                 |       |             |        |
| Male                   | 1.261 | 1.234–1.289 | <.0001 |
| Female                 | 1.000 |             |        |
| Age                    |       |             |        |
| 50–59                  | 1.000 |             |        |
| 60–69                  | 1.343 | 1.300–1.387 | <.0001 |
| 70–79                  | 1.818 | 1.761–1.877 | <.0001 |
| ≥80                    | 2.282 | 2.191–2.376 | <.0001 |
| Residence              |       |             |        |
| Seoul                  | 1.000 |             |        |
| Metropolitan city      | 0.982 | 0.958–1.007 | .155   |
| City                   | 1.122 | 1.098–1.147 | <.0001 |
| Rural                  | 1.208 | 1.179–1.237 | <.0001 |
| Income                 |       |             |        |
| Medical benefits       | 1.000 |             |        |
| 1st quartile           | 1.117 | 1.085–1.150 | <.0001 |
| 2nd quartile           | 1.131 | 1.098–1.165 | <.0001 |
| 3rd quartile           | 1.111 | 1.081–1.141 | <.0001 |
| 4th quartile           | 1.110 | 1.083–1.137 | <.0001 |
| Procedure type         |       |             |        |
| Unilateral             | 1.000 |             |        |
| Bilateral              | 1.108 | 1.072–1.145 | <.0001 |
| Other                  | 1.119 | 1.027–1.219 | .010   |
| Primary                | 1.000 |             |        |
| Revision               | 2.552 | 2.465–2.643 | <.0001 |
| Bed size               |       |             |        |
| Large (≥500)           | 0.992 | 0.960–1.026 | .649   |
| Medium (100–499)       | 1.014 | 0.981–1.047 | .4129  |
| Small (30–99)          | 1.000 |             |        |
| Length of stay (D)     |       |             |        |
| <15                    | 1.000 |             |        |
| 15–24                  | 1.044 | 1.017–1.072 | .001   |
| 25–34                  | 1.089 | 1.059–1.119 | <.0001 |
| ≥35                    | 1.146 | 1.114–1.178 | <.0001 |
| Transfusion            |       |             |        |
| No                     | 1.000 |             |        |
| Yes                    | 1.465 | 1.441–1.489 | <.0001 |

incidence of complications.<sup>[18,20]</sup> However, the effect of gender on the rate of postoperative complications in patients undergoing TKA has not yet been fully studied and further studies are needed.

It is known that older age is associated with more complications and higher mortality rate after TKA.<sup>[14,21–23]</sup> According to Easterlin et al, many surgical complications after TKA begin to increase at age 70 years and increase rapidly after age 80 years<sup>[22]</sup>, and Higuera et al report that the complications increase by 40% every 10 years in patients over age 65 years.<sup>[14]</sup> However, in this study, only cardiovascular complications and stroke showed increased risk with age, and respiratory complication increased in risk from age 80 years. On the other hand, in the case of PJI, there was a report that the incidence is high in young age. Meehan et al reported that the risk of periprosthetic joint infection was 1.8 times higher in patients younger than 50 years of age (odds ratio = 1.81, 95% CI = 1.33–2.47) compared with patients 65 years of age or older.<sup>[24]</sup> The results of this study similarly showed that groups under the age of 60 were at higher risk than the older age group. In general, age did not show a clear and consistent correlation with complications in this study.

**Table 8**  
Cox proportional hazard models of acute renal failure by variables.

| Multivariable analysis |        |               |        |
|------------------------|--------|---------------|--------|
| Variables              | HR     | 95% CI        | P      |
| Gender                 |        |               |        |
| Male                   | 1.324  | 1.252–1.401   | <.0001 |
| Female                 | 1.000  |               |        |
| Age                    |        |               |        |
| 50–59                  | 1.000  |               |        |
| 60–69                  | 0.775  | 0.729–0.823   | <.0001 |
| 70–79                  | 0.655  | 0.615–0.697   | <.0001 |
| ≥80                    | 0.719  | 0.653–0.791   | <.0001 |
| Residence              |        |               |        |
| Seoul                  | 1.000  |               |        |
| Metropolitan city      | 1.009  | 0.949–1.073   | 0.774  |
| City                   | 0.932  | 0.882–0.985   | 0.012  |
| Rural                  | 1.067  | 1.003–1.135   | 0.041  |
| Income                 |        |               |        |
| Medical benefits       | 1.000  |               |        |
| 1st quartile           | 0.994  | 0.927–1.067   | 0.877  |
| 2nd quartile           | 0.986  | 0.918–1.059   | 0.699  |
| 3rd quartile           | 0.894  | 0.837–0.956   | 0.001  |
| 4th quartile           | 0.814  | 0.765–0.866   | <.0001 |
| Procedure type         |        |               |        |
| Unilateral             | 1.000  |               |        |
| Bilateral              | 1.531  | 1.421–1.650   | <.0001 |
| Other                  | 1.140  | 0.927–1.402   | 0.214  |
| Primary                | 1.000  |               |        |
| Revision               | 25.357 | 24.306–26.454 | <.0001 |
| Bed size               |        |               |        |
| Large (≥500)           | 1.255  | 1.150–1.369   | <.0001 |
| Medium (100–499)       | 0.884  | 0.811–0.966   | 0.0056 |
| Small (30–99)          | 1.000  |               |        |
| Length of stay (D)     |        |               |        |
| <15                    | 1.000  |               |        |
| 15–24                  | 1.189  | 1.101–1.285   | <.0001 |
| 25–34                  | 1.252  | 1.155–1.358   | <.0001 |
| ≥35                    | 1.408  | 1.301–1.523   | <.0001 |
| Transfusion            |        |               |        |
| No                     | 1.000  |               |        |
| Yes                    | 1.338  | 1.282–1.397   | <.0001 |

In terms of residence, the risk level appeared to be somewhat higher in the rural group. It is known to date that few studies have conducted detailed research on this. In 2014, Wu et al, reported that patients living in the rural region had a 2.63 times higher risk of PJI than patients living in the urban region.<sup>[25]</sup> They mentioned that this may be caused by differences in more activities, delay in diagnosing the underlying disease, irregular treatment, difficulty paying medical expenses, social status, and education.<sup>[25]</sup> Our results supported it and showed the potential to increase the risk of other complications after surgery. The specific reasons for increased risk of rural residents need further investigation.

The highest-income group had a lower risk of sepsis, cardiovascular, respiratory complications, pulmonary embolism, ARF, and PJI. Studies on the between income and incidence of complications are lacking, but Bachmann revealed that in 2003, in the case of diabetic patients, the risk of diabetes complications in the low-income group is 3.6 to 4.3 times higher than in the high-income group.<sup>[26]</sup> They explain that low-income patients tend to be non-compliant and have a low rate of hospital visits.<sup>[26]</sup> According to other studies, differences in postoperative outcomes among socioeconomic classes were attributed to

**Table 9****Cox proportional hazard models of periprosthetic joint infection by variables.**

| Multivariable analysis |        |               |         |
|------------------------|--------|---------------|---------|
| Variables              | HR     | 95% CI        | P       |
| Gender                 |        |               |         |
| Male                   | 1.409  | 1.330–1.492   | <.0001  |
| Female                 | 1.000  |               |         |
| Age                    |        |               |         |
| 50–59                  | 1.000  |               |         |
| 60–69                  | 0.774  | 0.727–0.825   | <.0001  |
| 70–79                  | 0.633  | 0.594–0.676   | <.0001  |
| ≥80                    | 0.635  | 0.573–0.703   | <.0001  |
| Residence              |        |               |         |
| Seoul                  | 1.000  |               |         |
| Metropolitan city      | 1.001  | 0.938–1.068   | .978    |
| City                   | 0.947  | 0.894–1.003   | .063    |
| Rural                  | 1.034  | 0.969–1.104   | .308    |
| Income                 |        |               |         |
| Medical benefits       | 1.000  |               |         |
| 1st quartile           | 0.921  | 0.856–0.991   | .027    |
| 2nd quartile           | 0.940  | 0.873–1.012   | .099    |
| 3rd quartile           | 0.852  | 0.796–0.913   | <.0001  |
| 4th quartile           | 0.788  | 0.740–0.840   | <.0001  |
| Procedure type         |        |               |         |
| Unilateral             | 1.000  |               |         |
| Bilateral              | 1.551  | 1.436–1.675   | <.0001  |
| Other                  | 1.116  | 0.902–1.381   | .311    |
| Primary                | 1.000  |               |         |
| Revision               | 33.158 | 31.767–34.610 | <.0001  |
| Bed size               |        |               |         |
| Large (≥500)           | 1.251  | 1.141–1.372   | <0.0001 |
| Medium (100–499)       | 0.860  | 0.785–0.943   | .0013   |
| Small (30–99)          | 1.000  |               |         |
| Length of stay (D)     |        |               |         |
| <15                    | 1.000  |               |         |
| 15–24                  | 1.236  | 1.137–1.344   | <.0001  |
| 25–34                  | 1.300  | 1.192–1.418   | <.0001  |
| ≥35                    | 1.439  | 1.322–1.566   | <.0001  |
| Transfusion            |        |               |         |
| No                     | 1.000  |               |         |
| Yes                    | 1.155  | 1.103–1.210   | <.0001  |

**Table 10****Cox proportional hazard models of periprosthetic fracture by variables.**

| Multivariable analysis |        |               |        |
|------------------------|--------|---------------|--------|
| Variables              | HR     | 95% CI        | P      |
| Gender                 |        |               |        |
| Male                   | 1.090  | 1.039–1.143   | <.0001 |
| Female                 | 1.000  |               |        |
| Age                    |        |               |        |
| 50–59                  | 1.000  |               |        |
| 60–69                  | 0.796  | 0.757–0.838   | <.0001 |
| 70–79                  | 0.701  | 0.666–0.738   | <.0001 |
| ≥80                    | 0.767  | 0.710–0.827   | <.0001 |
| Residence              |        |               |        |
| Seoul                  | 1.000  |               |        |
| Metropolitan city      | 1.054  | 1.003–1.107   | .038   |
| City                   | 1.031  | 0.987–1.078   | .174   |
| Rural                  | 1.073  | 1.021–1.128   | .006   |
| Income                 |        |               |        |
| Medical benefits       | 1.000  |               |        |
| 1st quartile           | 1.143  | 1.078–1.212   | <.0001 |
| 2nd quartile           | 1.141  | 1.075–1.211   | <.0001 |
| 3rd quartile           | 1.108  | 1.048–1.170   | .000   |
| 4th quartile           | 1.079  | 1.026–1.136   | .003   |
| Procedure type         |        |               |        |
| Unilateral             | 1.000  |               |        |
| Bilateral              | 1.321  | 1.243–1.405   | <.0001 |
| Other                  | 1.059  | 0.898–1.250   | .497   |
| Primary                | 1.000  |               |        |
| Revision               | 13.774 | 13.269–14.299 | <.0001 |
| Bed size               |        |               |        |
| Large (≥500)           | 1.181  | 1.101–1.266   | <.0001 |
| Medium (100–499)       | 0.949  | 0.886–1.017   | .1384  |
| Small (30–99)          | 1.000  |               |        |
| Length of stay (D)     |        |               |        |
| <15                    | 1.000  |               |        |
| 15–24                  | 1.230  | 1.156–1.309   | <.0001 |
| 25–34                  | 1.350  | 1.266–1.440   | <.0001 |
| ≥35                    | 1.517  | 1.424–1.617   | <.0001 |
| Transfusion            |        |               |        |
| No                     | 1.000  |               |        |
| Yes                    | 2.222  | 2.152–2.295   | <.0001 |

differences in quality and provision of care.<sup>[16]</sup> However, considering that the hazard ratio of all complications did not decrease inversely as income increased, further research will be needed.

Several studies have confirmed that when BTKA is performed, the LOS, anesthesia time, and rehabilitation period can be shortened and there are benefits to patients and institution in terms of cost.<sup>[27,28]</sup> Despite these advantages, there was controversy over the safety of BTKA. According to Odum et al, simultaneous BTKA had higher complication odds compared to unilateral TKA (UTKA) (odds ratio=1.51, 95% CI=1.42–1.62).<sup>[27]</sup> Memtsoudis et al reported that staging BTKA had either a higher or similar incidence of complications compared to simultaneous BTKA.<sup>[29]</sup> This study supported results of those studies, as the complications HR of BTKA were consistently higher than that of UTKA.

Several studies report differences in the incidence of complications according to hospital volume. They revealed that the higher the hospital volume, the lower the risk of complications.<sup>[30,31]</sup> This study found that for all complications except

stroke, medium bed size hospitals showed lower HR than large bed size hospitals. The difference was thought to have occurred because the bed size did not match the hospital volume. There is a high possibility that there will be a bias in performing more complex surgeries at large hospitals. However, categorizing a facility as a specialized hospital (which may have smaller bed size) may be a more important factor than the bed size itself.<sup>[32]</sup> The relationship between complications and hospital size remains unclear and requires further study.

As for the LOS, our results indicated that the shorter the LOS, the less postoperative complications. There were inconsistencies in cardiovascular and respiratory complications according to the duration, but they showed significant results when LOS was more than 35 days. Several studies found that shorter LOS tended to show higher volume of procedures (an indicator of technical quality), lower rates of surgical complications, and reduced surgical episode spending.<sup>[33–35]</sup> If we explain to patients and families that shorter LOS reduces complications, we will be able to optimize unnecessary hospitalization periods. However, Bitar et al, reported that the longer LOS would indicate a patient with a

more complicated course of recovery after their primary TKA.<sup>[36]</sup> It supported that further clinical studies would be needed to determine the extent of LOS that could be reduced without sacrificing the quality or access of treatment.

In the case of use of transfusion, the risk was significantly higher in all complications. Glance et al, revealed that odds ratios were high in pulmonary complications (OR, 1.76; 95% CI, 1.48–2.09), sepsis (OR, 1.43; 95% CI, 1.21–1.68), thromboembolic complications (OR, 1.77; 95% CI, 1.32–2.38), and wound complications (OR, 1.87; 95% CI, 1.47–2.37) in patients undergoing non-cardiac surgery.<sup>[37]</sup> This could be explained by transfusion-induced immunomodulation. Immunomodulation may lead to immune activation, resulting in transfusion-related lung injury or immune suppression, increasing susceptibility to infectious complications.<sup>[38]</sup> The results of this study could be understood in this context.

Revision surgery showed high HR in all postoperative complications. According to Pulido et al, based on prospectively gathered data of 645 revision cases from a single institution, they reported a major and minor systemic (medical) complication rate of 7.44% and 5.27% respectively for revision TKA (compared to 4.91% and 3.40% for primary TKA) and a major and minor local (orthopaedic) complication rate of 1.26% and 6.51%, respectively for revision TKA (compared to 0.83% and 1.95% for primary TKA).<sup>[39]</sup> Our finding supported the findings of that study.

## 5. Limitations

Since this study was based on the claimed code data of the NHIS, it was estimated that there would be a lot of codes and data that are actually missing in the billing processes of each hospital. It may lead us to overestimate or underestimate complication rates, thereby reducing the generalizability of our study results. Due to the nature of nationwide study, it was impossible to determine the severity according to the result in each complication. In addition, it was not possible to observe or analyze other factors that could affect complications such as smoking, drinking, lifestyle, mental health, and patient's knee function and condition before surgery.

## 6. Conclusion

In this study, male, LOS ( $\geq 35$  days), use of transfusion and procedure type (BTKA, revision surgery) were shown to be risk factors of postoperative complications following TKA. We believe that interest in these various risk factors will minimize postoperative complications in the future and ensure continued access to TKA for all patients. It is also expected that this study will serve as the basis for similar studies in the future.

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