Does surgeon volume affect the outcome of total knee arthroplasties in a developing country? - A retrospective cohort study

Azeem Tariq Malik*, Syed Hamza Mufarrih, Arif Ali, Shahryar Noordin

Department of Surgery, Aga Khan University Hospital, Stadium Road, Karachi, Pakistan

ABSTRACT

Introduction: Recent studies have shown that in addition to patient factors, surgeon volume has influenced total knee arthroplasty (TKA) outcomes greatly. With recent propositions of regionalization of arthroplasties to higher volume centers, the need for further evidence is warranted.

Materials and methods: Retrospective Cohort Study done at Aga Khan University Hospital, Pakistan from January 2007 to December 2015. High Volume (HV) group was set as at least 50 TKAs/year and Low Volume (LV) was set as at most 25 TKAs/year. A total of 615 patients undergoing a unilateral or bilateral TKA were included in our study.

Results: LV group was associated with a higher length of stay (LOS) as compared to HV group in patients undergoing a bilateral TKA after adjusted logistic regression [OR 2.395 (1.47,3.91)]. We found no association between surgeon volume and postoperative complications.

Conclusion: Patients getting a bilateral TKA by LV surgeons were twice more likely to have a longer LOS as compared to HV group. Further research is warranted comparing all aspects and possible confounders to different variables before a conclusion can be made.

1. Introduction

Osteoarthritis is one of the most common ailing disability affecting the elderly population worldwide. With the principles of its management entailing reduction of pain and improving functional outcome, total knee arthroplasty (TKA) has been widely recognized as the gold standard in the treatment for advanced osteoarthritis of the knee [1–6]. The procedure is one of the most commonly performed operations in the US (with expectations that the total number would increase by over 600% in the next 20 years). Studies have shown that it successfully results in pain relief and improvement in the functional outcome in greater than 90% of the patients [3].

A significant percentage of patients (10–20%) however still continue to experience complications and report poor outcomes following this procedure [3]. With the ever increasing number of TKAs being performed worldwide, it is therefore a major concern that the cause of poor outcomes in the small, yet significant population be studied.

Recent studies have shown that in addition to patient factors (gender, age and comorbidities), provider factors such as surgeon volume have influenced TKA outcomes significantly [7–10]. There have been numerous studies looking at the association between hospital and surgeon volume and the outcomes on TKA using various parameters. Higher hospital volumes have been shown to be negatively associated with mortality rate [11]. Similarly, there have been many studies examining the influence surgeon volume on various TKA outcomes, but with varied results [12]. Recently, various strategies have been proposed which include regionalization of total joint arthroplasties to higher volume centers and adoption of standards.

Though there is a general trend towards better outcomes for higher volume surgeons, as past researches have shown, it is unclear that this trend positively affects adoption of regionalization policies. Past studies have recommended that further evidence and recommendations are required before any policy adoption takes place. Our study was aimed at investigating whether a lower surgeon volume was associated with a higher length of stay (LOS), a longer total operative time (TOT), higher intraoperative blood loss (EBL) and a higher risk of complications.

2. Materials and methods

2.1. Patients

This was a retrospective single center study done at Aga Khan University Hospital from January 2007 to December 2015. Aga Khan University Hospital is situated in the city of Karachi, Pakistan and...
approximately caters to a population of 20 million people. An annual number of 500 total hip and knee arthroplasties are performed by nine consultant orthopedic surgeons. Research protocol was developed prior to initiating the study. After approval from the Ethical Review Committee of Aga Khan University, we accessed records for all primary total knee arthroplasties done within this time period. All patients, regardless of gender, comorbidities and age who underwent a primary unilateral or bilateral TKA were included in the study. Those patients who underwent a revision TKA were excluded from the study. Those patients who had missing data were also excluded from the study. A total of 615 patients were included in our study. The surgeries were performed by consultant orthopedic surgeons with up to two residents assisting during the procedure. All patients underwent a standardized preoperative antibiotic protocol which was started an hour before surgery and continued for the next 24 h. All patients were given a standard protocol of DVT prophylaxis prior to the surgery. Intraoperatively, incision site was cleaned using povidone prep before draping. All patients underwent a standard postoperative protocol in the inpatient ward including mobilization and physiotherapy. The rehabilitation protocol was as follows - knee range of motion and full weight bearing as tolerated (WBAT) was started postoperatively on day one in case of patient undergoing general anesthesia. For patients with regional/epidural anesthesia, knee range of motion exercises were started postoperatively on day one and full weight bearing as tolerated (WBAT) was started after the epidural catheter was removed. Of note, in our part of the country majority of the rehabilitation protocols are carried out while the patient is admitted in the ward. This is one of the major factors why our mean length of stay is much higher when compared to our developing western counterparts. Patients were closely followed up after discharge for 30 days to monitor for any postoperative complications that might have developed. The study was reported in line with the STROCCS criteria [13]. In accordance with the declaration of Helsinki, the complete registered study details can be found at researchregistry.com (researchregistry2803).

2.2. Methods

Medical records were reviewed and noted on a proforma. We recorded demographic data, including surgeon ID, age, gender, co-morbidities, total anesthesia time, total operative time (TOT) (from incision to skin closure), length of stay (LOS), preoperative/postoperative hemoglobin (Hb) & hematocrit, and postoperative complications. Postoperative complications included UTI (urinary tract infection), SSI (surgical site infection), cardiac complications and DVT (deep venous thrombosis). Nadler’s formula was used to calculate the estimated blood volume of a person [14]. Estimated blood loss (EBL) was calculated using the Gross formula, which has been previously used for calculating blood loss in total hip arthroplasties [15]. Length of stay was defined from date of admission to date of discharge.

Surgeon Volume was calculated by calculating the frequencies of surgeons who performed at most 25 primary TKAs per year by a surgeon. We then divided the population into two groups: High volume Surgeons and Low Volume Surgeons by setting the mark at 50TKAs/year and 25 TKAs/year respectively. Those who performed at least 50 primary TKAs per year were included in the High Volume (HV) group and those who performed at most 25 primary TKAs were included in the Low Volume (LV) group. The groups were then further stratified into those who underwent a unilateral knee surgery and those who underwent a bilateral knee surgery to minimize the confounding effect brought about by operating both knees simultaneously.

Our primary outcome continuous variables (LOS, TOT and EBL) were skewed and did not fit normal distribution according to both Kolmogorov-Smirnov and Shapiro-Wilk tests (p < 0.05) therefore medians were used for representing data. Continuous data – EBL(ml), LOS(days), and TOT(min) were dichotomized into two groups based on their median. Patient demographics in both groups were analyzed using appropriate Mann-Whitney U-Tests for continuous variables (Age and BMI) and Pearson Chi-Square tests for categorical variables.

In both Unilateral and Bilateral TKA groups, the groups were not comparable in terms of age, gender and several comorbidities. Since our sample size was too small to allow for appropriate matching, we decided to adjust for these factors in all logistic regression models.

Univariate analyses was also carried out to better discern for significant predictors and these were then included in a multivariate logistic regression model. A p-value of less than or equal to 0.10 was set as the threshold for including these in the multivariate analysis. All significant predictors from the univariate analysis and significant co-variates from the original comparison between groups were included in the final binomial logistic regression model. Values were considered significant at the 5% level.

3. Results

A total of 615 patients meeting the inclusion criteria were included in our study. Out of 615, 344 (55.9%) belonged to the HV group and 271 (44.1%) patients belonged to the LV group. Demographics for the two groups are shown in Table 1.

Subgroup comparison showed that in the Unilateral TKA, the volume groups were not similar in terms of age and hypothyroidism (Table 2). In Bilateral TKA, the volume groups were not similar in terms of age, gender, hyperlipidemia and hypertension (Table 5). All of these factors will be theoretically defined as ‘co-variates’ in this article. All of these co-variates will be adjusted for in the final binomial logistic regression model regardless of whether they are independent significant predictors of each of our primary outcome variables (LOS, TOT, EBL, Postoperative SCU stay and Postoperative complications.)

3.1. Unilateral TKA

The groups were not comparable with respect to age (p = 0.000) and the presence of diabetes (p = 0.05) and hypothyroidism (p = 0.018). Univariate analysis showed that patients operated by Low volume surgeons were associated with a higher risk of having UTI (p = 0.007) and SSI (p = 0.026). Surgeries done by the LV group were not associated with a higher LOS (> 7 days) as compared to those done by the HV group. In addition, LV group was not associated with a higher EBL (p = 0.092), TOT (p = 0.154), Postop SCU stay (p = 0.10) and Complications during 30 days (p = 0.113).

Logistic regression analysis was also done for LOS (p = 0.492), EBL (p = 0.128), TOT (p = 0.099) to control for the significant co-variates (Age and Hypothyroidism). All values remained insignificant after adjustment. Univariate analysis for SSI and UTI was then conducted to further discern for factors associated with the presence of these outcomes (Table 3).

All variables with a p-value of less than 0.10 were included in a logistic regression model. Also since the HV and LV groups were not similar in terms of age and the comorbid (hypothyroidism) they were also added into the logistic regression model regardless if they were significant independent predictors of UTI and SSI or not.

Following adjusted logistic regression, the only variable that remained significant for a UTI was the presence of Postoperative SCU stay. None of the co-variates remained significant after logistic regression in predicting the presence of a SSI (Table 4).

3.2. Bilateral TKA group

Comparison was then carried out between HV and LV groups in the Bilateral TKA population (Table 5).

HV and LV groups in Bilateral TKA were not similar in terms of Sex,
The document discusses a study comparing the outcomes of unilateral and bilateral total knee arthroplasty (TKA) performed by high and low volume surgeons. The authors adjusted for potential confounding factors such as age, sex, comorbidities, and other variables. They found that lower surgeon volume was associated with a significantly longer length of stay (LOS) and higher odds of LOS > 9 days compared to higher volume surgeons. The study also highlighted the importance of adherence to evidence-based processes of care in managing complications such as urinary tract infections (UTI) and surgical site infections (SSI).

### Table 1: Preoperative, Intraoperative and Postoperative Demographics of Study Population

|                      | Unilateral TKA (n = 271) | Bilateral TKA (n = 344) |
|----------------------|--------------------------|------------------------|
|                      | High Volume (≥ 50 TKAs/y) | Low Volume (≤ 25 TKAs/y) | High Volume (≥ 50 TKAs/y) | Low Volume (≤ 25 TKAs/y) |
|                      | (n = 149)                | (n = 122)              | (n = 185)               | (n = 160)               |
| Sex                  |                          |                        |                          |                        |
| Male                 | 40 (26.8%)               | 39 (32.0%)             | 23 (12.5%)              | 40 (25.0%)              |
| Female               | 109 (73.2%)              | 83 (68.0%)             | 161 (87.5%)            | 120 (75.0%)            |
| Mean Age (years)     | 65.3 ± 9.3               | 59.7 ± 11.3            | 62.7 ± 9.1             | 60.5 ± 8.8             |
| Mean BMI (kg/m²)     | 29.9 ± 4.7               | 30.5 ± 7.6             | 31.5 ± 5.8             | 31.8 ± 5.8             |
| CoMorbids            |                          |                        |                          |                        |
| Diabetes             | 49 (32.9%)               | 27 (22.1%)             | 54 (29.3%)             | 44 (27.5%)             |
| Hypertension         | 90 (60.4%)               | 62 (50.8%)             | 124 (67.4%)            | 80 (50.0%)             |
| Asthma               | 7 (4.7%)                 | 7 (5.7%)               | 10 (5.4%)              | 9 (5.6%)               |
| Hyperthyroidism      | 1 (0.7%)                 | 0                      | 1 (0.5%)               | 3 (1.9%)               |
| Hypothyroidism       | 3 (2.0%)                 | 10 (8.2%)              | 13 (7.1%)              | 9 (5.6%)               |
| CAD                  | 15 (10.1%)               | 16 (13.1%)             | 14 (7.6%)              | 10 (6.2%)              |
| Dyslipidemia         | 6 (4.0%)                 | 2 (1.6%)               | 13 (7.1%)              | 1 (0.6%)               |
| CKD                  | 3 (2.0%)                 | 5 (4.1%)               | 4 (2.2%)               | 5 (3.1%)               |
| COPD                 | 0 (0%)                   | 1 (0.8%)               | 1 (0.5%)               | 1 (0.6%)               |
| Hypercholesterolemia | 3 (2.0%)                 | 2 (1.6%)               | 4 (2.2%)               | 0                      |
| Median LOS (days) [IQR] | 8.0 [6.0–9.0]        | 7.0 [6.0–9.0]          | 9.0 [8.0–10.0]         | 9.0 [8.0–12.0]         |
| Median TOT (min) [IQR] | 140.0 [124.75–160.0]     | 135.0 [115.75–160.0]   | 262.0 [240.75–298.5]   | 240.0 [207.25–269.0]   |
| Median EBL (ml) [IQR] | 576.25 [361.9–727.6]     | 497.5 [285.3–727.6]    | 774.35 [524.6–1130.25] | 790.7 [499.2–1052.7]   |
| Postop SCU            | 3 (2.0%)                 | 7 (5.7%)               | 7 (3.8%)               | 11 (6.9%)              |
| Complications         |                          |                        |                          |                        |
| UTI                  | 1 (0.7%)                 | 8 (6.6%)               | 3 (1.6%)               | 3 (1.9%)               |
| DVT                  | –                        | –                      | –                      | –                      |
| SSI                  | 0                        | 4 (3.3%)               | 1 (0.5%)               | 0                      |
| Cardiac              | 0                        | 3 (2.5%)               | 5 (2.7%)               | 4 (2.5%)               |
| Complications during 30 days | 1 (0.7%) | 4 (3.3%) | 9 (4.9%) | 2 (1.2%) |

### Abbreviations:
- CAD = Coronary artery disease
- CKD = Chronic kidney disease
- COPD = Chronic obstructive pulmonary disease
- LOS = Length of stay
- EBL = Estimated blood loss
- SCU = Special care unit
- UTI = Urinary tract infection
- DVT = Deep venous thrombosis
- SSI = Surgical site infection
- IQR = Interquartile range

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Age and comorbidities (Dyslipidemia, Hypertension). Therefore, we decided to adjust these for potential confounding effects in logistic regression regardless of whether they were significant independent predictors for primary outcome variables.

LOS was dichotomized into > 9 days and ≤ 9 days based on the median cut off value. Similarly, TOT and EBL were also dichotomized into their respective groups based on the cut off median value. Analysis between two groups showed that LV group was associated with a higher odds of LOS > 9 days as compared to the HV group. Interestingly, HV surgeons tend to have a longer operating time as compared to LV group. This is probably based on surgeon preference and therefore we decided on not further initiating a univariate analysis on this variable.

Results also showed that surgeon volume was not associated with postoperative complications.

Logistic Regression Analysis was done for the primary continuous outcome variables (LOS, TOT, EBL) while adjusting for each other. This signified significant independent predictors causing an increased effects in logistic regression model and adjusted for each other.

Significant independent predictors with a p-value of < 0.1 were then added into a logistic regression model and adjusted for each other. Age, Sex, Hypertension and dyslipidemia were also included in the regression model to account for the differences present between the groups in the first analysis (Table 6).

Results showed that the only variables that remained significant for a LOS > 9 days after adjusted logistic regression analysis were a lower surgeon volume of ≤ 25 TKAs/year (OR 2.395 [1.47, 3.91]) and higher BMI (OR 1.07 [1.02, 1.11]). We found that patients who received a bilateral TKA by LV surgeons were twice likely to stay longer than those who got one by the HV group (Table 7).

### 4. Discussion

Our study found out that patients who underwent a bilateral TKA by a surgeon who performed at least 50 TKAs/year were associated with a significantly lower length of stay when compared to those who underwent a bilateral TKA by a surgeon who did at most 25 TKAs/year.

Higher surgeon volume was also associated with a higher total operative time in bilateral TKA.

We also found that lower surgeon volume was an independent predictor of UTI and SSI in patients undergoing a unilateral TKA, however this significant was lost after adjusting for other significant predictors and covariates for UTI.

Our findings are consistent with prior work showing that a higher surgeon volume is associated with a significantly shorter LOS as compared to their lower surgeon volume counterparts.

Kreder et al. conducted a retrospective review in 14,352 patients undergoing a total knee replacement and concluded that a lower surgeon volume (< 14 TKAs/y) was associated with a longer LOS as compared to a HV group (> 42 TKAs/y). Similar to our study he also found no association between surgeon volume and postoperative infection and medical complications.

Paterson et al. similarly conducted another retrospective review and also concluded that LV surgeon (< 35 TKAs/y) were associated with a longer LOS as compared to their HV counterparts (> 50TKAs/y). He also found no association between surgeon volume and postoperative complications.

Both Wei et al. and Styron et al., also conducted retrospective review of patients undergoing primary TKA and concluded with similar findings [16,17].

Literature has suggested that a possible explanation to this would be that adherence to evidence based processes of care in HV surgeons...
would result in a decrease in LOS. Studies done have shown a weak negative correlation between surgeon volume and number of missed evidence based processes of care [18].

In addition, it is thought that utilization of clinical care pathways can result in a shorter LOS [19,20]. Further research would be required to establish and see whether there is a correlation between the use of clinical care pathways, evidence based process of care measures and surgeon volume to help in understanding the discrepancy in LOS between the two groups.

We found no association between surgeon volume and LOS in the Unilateral TKA group. A possible reason for this could be that LV surgeons are mostly either those who are fresh out of training or those who rarely get patients for knee replacement. Majority of patients would prefer going to a well-experienced doctor if both knees are being operated on. Since they have had experience of performing unilateral TKAs during the residency more than bilateral TKAs, they are more accustomed to the process of placing implants. However, no such questionnaire based study has been done which investigates surgeon’s comfort with performing bilateral TKAs right after residency. Future studies might be able to yield an answer to such a question.

An interesting finding in our study is the presence of a prolonged intraoperative time in bilateral TKAs being performed by HV surgeons. There could be multiple reasons to such a phenomenon. Based off our center, the high volume surgeon routinely used a tourniquet. Moreover before closing the wound the high volume surgeon would have the tourniquet removed to ensure hemostasis before closing the wound. Furthermore the high volume surgeon also injected periarticular regional analgesia in the knees prior to closing the wound. All of these would result in a decrease in LOS. Studies done have shown a weak negative correlation between surgeon volume and number of missed evidence based processes of care [18].

In addition, it is thought that utilization of clinical care pathways can result in a shorter LOS [19,20]. Further research would be required to establish and see whether there is a correlation between the use of clinical care pathways, evidence based process of care measures and surgeon volume to help in understanding the discrepancy in LOS between the two groups.

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On the basis of Chi-square, we did show an independent significance between low surgeon volume and an increased risk of SSIs in patients undergoing Unilateral TKA. However, this significance was lost after adjusted logistic regression analysis.

Similar to the findings in our study, Yasunaga et al. reported no association between surgeon volume and the risk of developing DVT [22].

Mulwijk et al., Wei et al. and Katz et al. based on their results concluded that LV surgeons are more likely to be associated with a diagnosis of deep DVT [8,17,23]. However, they failed to identify if the findings in our study, Yasunaga et al. reported no association between surgeon volume and the risk of developing DVT [22].

Multivariate Logistic Regression Analysis with (LOS > 9 days) set as Yes. Values given as ‘1’ are used as the reference group during comparison.

| Bilateral TKA (n = 344) | High Volume (≥ 50 TKAs/y) | Low Volume Group (≤ 25 TKAs/y) | P-Value |
|-------------------------|---------------------------|--------------------------------|---------|
| Sex                     |                           |                                |         |
| Male                    | 23 (12.5%)                | 40 (25.0%)                     | 0.003   |
| Female                  | 161 (87.5%)               | 120 (75.0%)                    |         |
| Mean Age (years)        | 62.7 ± 9.1                | 60.5 ± 8.8                     | 0.006†  |
| Mean BMI (kg/m²)        | 31.5 ± 5.8                | 31.8 ± 5.8                     | 0.674†  |
| CoMorbids               |                           |                                |         |
| Diabetes                | 54 (29.3%)                | 44 (27.5%)                     | 0.705   |
| Hypertension            | 124 (67.4%)               | 80 (50.0%)                     | 0.001   |
| Asthma                  | 10 (5.4%)                 | 9 (5.6%)                       | 0.939   |
| Hyperthyroidism         | 1 (0.5%)                  | 3 (1.9%)                       | 0.251   |
| Hypothyroidism          | 13 (7.1%)                 | 9 (5.6%)                       | 0.586   |
| CAD                     | 14 (7.6%)                 | 10 (6.2%)                      | 0.622   |
| Dyslipidemia            | 13 (7.1%)                 | 1 (0.6%)                       | 0.003   |
| CKD                     | 4 (2.2%)                  | 5 (3.1%)                       | 0.581   |
| COPD                    | 1 (0.5%)                  | 1 (0.6%)                       | 0.921   |
| Hypercholesterolemia    | 4 (2.2%)                  | 0                              | 0.061   |
| LOS (days)              |                           |                                | 0.001   |
| ≤ 9 days                | 128 (70.3%)               | 82 (52.6%)                     |         |
| > 9 days                | 54 (29.7%)                | 74 (47.4%)                     |         |
| TOT (min)               | 112 (61.5%)               | 57 (36.5%)                     | 0.000   |
| EBL (ml)                | > 253.5 min               | 57 (36.5%)                     |         |
| > 780.0 ml              | 89 (48.9%)                | 83 (51.9%)                     | 0.583   |
| Postop SCU Complications| 7 (3.8%)                  | 11 (6.9%)                      | 0.231   |
| UTI                     | 3 (1.6%)                  | 3 (1.9%)                       | 0.863   |
| DVT                     | –                        | –                              |         |
| SSI                     | 1 (0.5%)                  | 0                              | 0.350   |
| Cardiac                 | 5 (2.7%)                  | 4 (2.5%)                       | 0.900   |
| Complications during 30 days | 9 (4.9%)  | 2 (1.2%)                      | 0.056   |

Table 6
Univariate analysis for the significant predictor (LOS > 9 days) using Mann-Whitney U test and Pearson Chi-Square test. For including variables in multivariate logistic regression model, we used p-values less than 0.10 as the marker for inclusion (given in bold).

| Bilateral TKA (n = 344) | High Volume (≥ 50 TKAs/y) | Low Volume Group (≤ 25 TKAs/y) | P-Value |
|-------------------------|---------------------------|--------------------------------|---------|
| Sex                     |                           |                                |         |
| Male                    | 23 (12.5%)                | 40 (25.0%)                     | 0.003   |
| Female                  | 161 (87.5%)               | 120 (75.0%)                    |         |
| Mean Age (years)        | 62.7 ± 9.1                | 60.5 ± 8.8                     | 0.006†  |
| Mean BMI (kg/m²)        | 31.5 ± 5.8                | 31.8 ± 5.8                     | 0.674†  |
| CoMorbids               |                           |                                |         |
| Diabetes                | 54 (29.3%)                | 44 (27.5%)                     | 0.705   |
| Hypertension            | 124 (67.4%)               | 80 (50.0%)                     | 0.001   |
| Asthma                  | 10 (5.4%)                 | 9 (5.6%)                       | 0.939   |
| Hyperthyroidism         | 1 (0.5%)                  | 3 (1.9%)                       | 0.251   |
| Hypothyroidism          | 13 (7.1%)                 | 9 (5.6%)                       | 0.586   |
| CAD                     | 14 (7.6%)                 | 10 (6.2%)                      | 0.622   |
| Dyslipidemia            | 13 (7.1%)                 | 1 (0.6%)                       | 0.003   |
| CKD                     | 4 (2.2%)                  | 5 (3.1%)                       | 0.581   |
| COPD                    | 1 (0.5%)                  | 1 (0.6%)                       | 0.921   |
| Hypercholesterolemia    | 4 (2.2%)                  | 0                              | 0.061   |
| LOS (days)              |                           |                                | 0.001   |
| ≤ 9 days                | 128 (70.3%)               | 82 (52.6%)                     |         |
| > 9 days                | 54 (29.7%)                | 74 (47.4%)                     |         |
| TOT (min)               | 112 (61.5%)               | 57 (36.5%)                     | 0.000   |
| EBL (ml)                | > 253.5 min               | 57 (36.5%)                     |         |
| > 780.0 ml              | 89 (48.9%)                | 83 (51.9%)                     | 0.583   |
| Postop SCU Complications| 7 (3.8%)                  | 11 (6.9%)                      | 0.231   |
| UTI                     | 3 (1.6%)                  | 3 (1.9%)                       | 0.863   |
| DVT                     | –                        | –                              |         |
| SSI                     | 1 (0.5%)                  | 0                              | 0.350   |
| Cardiac                 | 5 (2.7%)                  | 4 (2.5%)                       | 0.900   |
| Complications during 30 days | 9 (4.9%)  | 2 (1.2%)                      | 0.056   |

Table 7
Multivariate Logistic Regression Analysis with (LOS > 9 days) set as Yes. Values given as ‘1’ are used as the reference group during comparison.

| Preoperative Factors | Odds Ratio [95% CI] | P-Value |
|----------------------|---------------------|---------|
| Age                  | 60.0 [55.0–68.0]    | 0.800†  |
| Sex                  | 0.580               |         |
| Male                 | 25 (19.5%)          |         |
| Female               | 103 (80.5%)         | 0.014†  |
| BMI (kg/m²)          | 31.8 [28.3–36.5]    | 0.001   |
| Surgeon Volume       | ≥ 50 TKAs/y         |         |
| LV                   | 54 (42.2%)          |         |
| ≥ 25 TKAs/y          | 74 (57.8%)          |         |
| CoMorbids            |                     |         |
| Diabetes             | 39 (30.5%)          | 0.574   |
| Hypertension         | 79 (61.7%)          | 0.510   |
| Asthma               | 5 (3.9%)            | 0.364   |
| Hyperthyroidism      | 1 (0.8%)            | 0.593   |
| Hypothyroidism       | 10 (7.8%)           | 0.448   |
| CAD                  | 13 (10.2%)          | 0.088   |
| Dyslipidemia         | 7 (5.5%)            | 0.339   |
| CKD                  | 4 (3.1%)            | 0.680   |
| COPD                 | 2 (1.6%)            | 0.069   |
| Hypercholesterolemia | 3 (2.3%)            | 0.154   |
| Intraoperative Factors|                     |         |
| TOT (min)            | > 253.5 min         | 0.755   |
| EBL (ml)             | > 780.0 ml          | 0.843   |
| Postoperative Factors|                     |         |
| UTI                  | 3 (2.3%)            | 0.537   |
| SSI                  | 0                   | 0.434   |
| DVT                  | 0                   | –       |
| Cardiac              | 5 (3.9%)            | 0.268   |
surgeon’s operating list will vary from a couple of arthroplasties with fractures and other elective procedures thrown within. Regardless, there is still a need for uniformity to be established between threshold volumes to allow better estimation of the volume-outcome relationships.

As with all retrospective studies there is a potential for uncontrolled confounding factors which can result in marked bias. Another limitation to the study is that data was not gathered on the types of implant used which may have some effect on the postoperative outcome in patients. Data was also not gathered with respect to postoperative readmissions which if studied can also be a useful tool for analyzing outcome in patients. We were only limited to gathering information about complications limited to 30 days. A longer and close followup of 90-days to several years could also give an insight into whether surgeon volume has an influence on the long-term outcome and survivorship following TKA.

5. Conclusion

Based off our study and sample size, we conclude that lower surgeon volume negative impacts length of stay in patients undergoing bilateral TKA. However, we found no association between surgeon volume and postoperative complications. While our findings trend towards better outcomes for higher volume surgeons, we believe that there is not sufficient evidence yet to fully support the concentration of bilateral TKAs to higher volume surgeons only. Further research is warranted comparing all aspects and possible confounders to different variables before a conclusion can be made.

Ethical approval

Exempt from Ethical review committee since this was a retrospective study.

Sources of funding

No funding required.

Author contribution

Azeem Tariq Malik was involved in conception of idea, data collection and analysis, manuscript writing and review. Syed Hamza Mufarrib and Arif Ali were involved in data collection. Shahryar Noordin was involved in review of manuscript.

Conflicts of interest

No conflicts of interest.

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