

# Costs analysis of Staged Versus Simultaneous Bilateral Total Knee and Hip Arthroplasty: a university affiliated hospital survey of 1579 Chinese patients

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## Research article

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## Abstract

**Background** Total knee arthroplasty (TKA) and total hip arthroplasty (THA) are required for many patients. No recent studies that concentrate on the costs for each of the payment items both for TKA and THA when comparing simultaneous bilateral procedures with staged arthroplasty. This study aimed to evaluate the medical costs, length of stay (LOS), blood transfusion, and in-hospital complications in patients undergoing simultaneous TKA or THA and staged TKA or THA.

**Methods** A retrospective cohort study was conducted by analyzing 1,579 patients from a single institution. All patients who underwent primary bilateral TKA or THA from 2013 to 2018 were divided into three groups: TKA, THA and all patients. Then, we grouping simultaneous bilateral groups and staged bilateral groups in these three groups respectively. Finally, these two sub-groups (simultaneous bilateral groups and staged bilateral groups) were compared between the three groups (TKA, THA, and pooled groups).

**Results** All categories of medical costs, except for materials fees which were higher in the simultaneous bilateral THA and pooled groups but with no statistical significance, were lower in the simultaneous TKA, THA and pooled simultaneous groups. The total average medical costs in simultaneous and staged bilateral TKA groups were \$15,535.621 and \$16,747.192, ( $p < 0.001$ ), respectively; THA groups were \$15,046.210 and \$16,126.808, ( $p = 0.003$ ), respectively; pooled groups were \$16,506.971 and \$15,467.561, ( $p < 0.001$ ), respectively. All costs were presented in the United States dollar. The highest and lowest costs were materials fees and nursing care fees. No significant differences were found for five common co-morbidities and postoperative complications between the two sub-groups in three groups. The simultaneous groups had a shorter LOS, a higher incidence of blood transfusion than staged groups whether it is TKA groups or THA or pooled groups.

**Conclusions** These results indicate that simultaneous bilateral TKA and THA with a shorter LOS is more economical than staged bilateral TKA and THA. Counts of complications were not affected by the choice for staged or simultaneous bilateral total arthroplasty. But blood transfusion was more prevalent in the simultaneous groups both for TKA and THA.

## Introduction

Total Knee Arthroplasty (TKA) and Total Hip arthroplasty (THA) are cost-effective procedures for patients with advanced arthropathies, such as osteoarthritis (OA), rheumatoid arthritis (RA), and hip fracture, which can improve the quality of life for these patients significantly [1–3]. With the aging population, arthropathy incidence is projected to continue growing in many countries [2, 4–6]. A recent study from the U.S predicted the volume of total joint arthroplasty (TJA) and concluded that THA is projected to grow 71%, to 635,000 procedures, and TKA is projected to grow 85%, to 1.26 million procedures, by 2030 [4].

Besides, the rising number of arthroplasty procedures, corresponding with an increased yearly cost, will result in a huge economic burden for both the families and the health care system [2, 7–10]. As China's healthcare expenditures are soaring [11], the government has sought to reduce the overall cost of arthroplasty procedures by shortening average LOS, strengthening the supervision of surgical procedures and management of purchasing medical disposable materials.

Usually, bilateral TKA and THA can be performed simultaneously under the same anesthetic during one hospitalization, or as staged bilateral procedures, with 2 unilateral arthroplasties under separate anesthetics and hospitalizations. These are two different strategy of surgical procedures. However, there exists debate regarding performing staged bilateral TKA or THA with an interval between procedures or simultaneous bilateral TKA or THA patients, primarily because of the controversy about the outcomes of two procedures [7, 12]. The comparison between the two types of surgery is not consistent. Therefore, the surgeons and patients need some new evidence to decide whether to perform simultaneous bilateral TKA (or THA) or staged TKA (or THA).

Previous studies about simultaneous bilateral TKA versus staged TKA and simultaneous THA vs. staged THA have made some progress. But their research focuses always concentrated on clinical outcomes, such as operative and anesthetic times, EuroQol-5D index, health-related quality of life, blood loss, Harris hip score, and in-hospital mortality rates [1, 12–15]. Whereas to the best of our knowledge, no recent study has presented a direct comparison of actual hospital costs for both TKA and THA. For any decisions are not usually based solely on costs or clinical outcomes, but a combination of them. Yet there is no consensus on which procedure (simultaneous vs staged bilateral TKA or THA) is better.

In our research, we sought to provide data on this issue by analyzing 1,579 patients referred to our hospital. This study aimed to investigate differences in cost, in-hospital complications, blood transfusion, and length of stay in three groups (TKA, THA, and pooled patients groups), respectively. Besides, subgroup analysis of cost, in-hospital complications, blood transfusion, and length of stay were performed in staged and simultaneous bilateral TJA groups.

## Methods

### Study Design and Data Sources

After Ethics Committee of the Affiliated Hospital of Qingdao University approval, we performed a retrospective analysis of patients who undergone primary TKA or THA procedures discharged from January 1th, 2013, to December 31th, 2018, referred to the Affiliated Hospital of Qingdao University, a 5046-bed urban, third grade class A, medical-school-affiliated hospital in Qingdao, Shandong (third grand class A is the highest level in the hospital classification in China).

Anonymous clinical data were extracted from the hospital information system (HIS) of our hospital, which were consisted of baseline information of the patient, in-hospital costs, LOS, indications of operation by International Classification of Diseases, 10th revision (ICD-10), in-hospital complications (Complications include hematoma, surgical site infection, periprosthetic joint infection, periprosthetic femoral fracture, dislocation, aseptic

loosening, shock, myocardial infarction, heart failure, pulmonary embolism, cerebral infarction, delirium, acute stress ulcer, arrhythmia, acute renal injury, deep vein thrombosis, pneumonia, atelectasis, urinary tract infection and urinary retention.), blood transfusion, and detailed healthcare expenditure information.

Patients were included in the analysis if all cost, in-hospital complication, LOS and demographic data were available. Patients were divided into three groups-THA, TKA, and all patients, and then divided into two subgroups according to whether they were undergoing simultaneous bilateral TJA or staged bilateral TJA.

## Primary Outcome: Direct Medical Costs

Total medical expenses were mainly composed of bed fees, fees of general therapy, nursing care fees, check-up and laboratory test fees, surgical fees, drug fees, materials fees and charge for medical service. Detail introduction about all kinds of costs are shown in Table 1(All tables are at the end of the article). Total hospital costs of the staged group used pooled data of the two procedures. To offset the influence of inflation and economic growth and to reflect the real dollar value, all expenditure variables in the present study were adjusted to present Chinese currency values using the Consumer Price Index (CPI)[16], and then all values were converted to US Dollars (USD) with the exchange rate[17] of 1 USD = 6.43 yuan (the averaged exchange rate throughout the study period from 2013 to 2018).

Table 1  
The introduction of all kinds of medical costs for patients

Items	Description
Total medical expenses	The sum of health expenditures
Bed fees	Relatively fixed expenses for the bed used by patients
Fees of general therapy	Including dressing change, injection, catheterization, oxygen absorption and other costs
Nursing care fees	Relatively fixed cost of caring for patients every day.
Check-up and laboratory test fees	Various medical equipment inspection costs
Surgical fees	The cost of the surgical operation alone, not including other expenses incurred during the hospitalization
Charge for medical service	Embodying the technical value of medical staff
Drug fees	Refer in particular to drugs used by patients
Materials fees	A combination of various hygienic consumables cost

## Secondary Outcomes: In-hospital Complications, Blood Transfusion, And LOS

One of the secondary outcomes of interest are in-hospital complications (including acute myocardial infarction, deep venous thrombosis, pulmonary embolism, ileus, renal failure, pneumonia, and orthopedic-specific complications). Other secondary outcomes of interest included perioperative transfusion rate, and LOS which was defined as the duration of hospital admission before and after surgery. As for the staged surgery group, a total length of days of both surgeries was used as final LOS.

## Statistical Analysis

The normality of continuous variables was assessed using the Kolmogorov-Smirnov test or Shapiro-Wilk test. Non-normally distributed variables were presented as medians and interquartile ranges (IQR, the range between the 25th and 75th percentile) and categorical variables were presented by counts and percentages. Demographic and clinical data of patients were compared between groups with the chi-squared test for categorical variables and the Mann-Whitney U test for continuous variables. A two-sided  $p < 0.05$  was considered as statistical significance. All statistical analyses were performed using SPSS software version 25.0(IBM Corporation, USA).

## Results

### Baseline Characteristics

Among 1,579 patients, 929 cases were simultaneous total arthroplasty patients, and 650 cases were staged bilateral total arthroplasty patients. The baseline characteristics were shown in Table 2. A total of 1,180 patients underwent TKA, of which 789 were simultaneous TKA patients and 391 were staged THA patients. Simultaneous TKA patients were younger (64 vs. 68 years,  $p < 0.001$ ) compared with staged THA patients. For the distribution of gender, 82.51% were female for simultaneous TKA patients and 80.31% for staged THA patients. But no statistical significance between the two groups( $p = 0.356$ ). The body mass index (BMI) in two simultaneous and staged groups were 27.34 and 27.64 respectively. No significant differences were found between the two groups in regard to BMI and five common preoperative complication(co-morbidities):hypertension, coronary heart disease, diabetes, history of cerebral infarction, disease of respiratory system (Table 2).

Table 2  
Baseline characteristics of patients

Groups	Total knee arthroplasty			Total hip arthroplasty			Pooled groups	
	Simultaneous (n = 789)	Staged (n = 391)	P Value	Simultaneous (n = 140)	Staged (n = 259)	P Value	Simultaneous (n = 929)	Staged (n = 391)
Age, median(IQR) years <sup>a</sup>	64(60,69)	68(63,73)	< 0.00	53(47,60)	58(49,64)	0.001	63(58,68)	64(58,70)
Gender, (female) <sup>b</sup>	651(82.51%)	314(80.31%)	0.356	42(30.00%)	85(32.82%)	0.564	693(74.60%)	399(61.3%)
BMI, median(IQR) kg/m <sup>2</sup> <sup>a</sup>	27.34(24.92,30.08)	27.64(25.39,30.04)	0.149	24.55(21.88,26.98)	24.57(22.58,27.55)	0.279	26.99(24.23,29.66)	26.73(24.23,29.66)
Hypertension, yes <sup>b</sup>	375(47.50%)	206(52.69%)	0.095	20(14.29%)	39(15.10%)	0.836	395(42.52%)	245(37.6%)
Diabetes, yes <sup>b</sup>	124(15.70%)	71(18.16%)	0.228	7(5.00%)	9(3.47%)	0.459	131(14.105%)	80(12.31%)
Coronary heart disease, yes <sup>b</sup>	126(15.97%)	64(16.37%)	0.861	1(0.71%)	4(1.54%)	0.477	127(13.67%)	68(10.46%)
Disease of respiratory system, yes <sup>b</sup>	35(4.44%)	23(5.88%)	0.280	3(2.14%)	8(3.09%)	0.582	38(4.09%)	31(4.77%)
History of cerebral infarction, yes <sup>b</sup>	48(6.08%)	21(5.37%)	0.623	2(1.43%)	4(1.54%)	0.928	50(5.38%)	25(3.85%)
IQR: Inter Quartile Range; BMI: Body Mass Index								
a:Continuous data were presented as median (IQR) and compared by Mann-Whitney U test;								
b:Categorical variables were expressed by counts and percentages and compared by the Chi-square test or the Fisher's exact test, as appropriate.								

399 patients received THA, consisting of 140 who underwent simultaneous bilateral THA and 259 staged THA. The patients of staged bilateral THA were older (58 vs. 53 years,  $p < 0.01$ ) than those simultaneous THA patients. The gender distribution was neither different (42, female vs. 85, female,  $p = 0.564$ ) between simultaneous THA patients and staged bilateral THA patients, and no significant difference was found in BMI and five common preoperative complications. As shown in Table 2.

Similar to trends for TKA and THA, simultaneous total arthroplasty were performed more frequently in younger patients (63 vs. 64 years,  $p < 0.05$ ). For patients pooled together, there was a difference in gender distribution (693, female vs. 399, female,  $p < 0.01$ ) between simultaneous total arthroplasty patients and staged bilateral total arthroplasty patients. But no significant difference in BMI and five common co-morbidities (Table 2).

## Clinical Characteristics

A summary of the clinical data of the patients of the three groups is shown in Table 3. Simultaneous TKA patients have a higher incidence of blood transfusion (302, yes vs. 32, yes,  $p < 0.000$ ), and with a shorter LOS (9 vs. 18,  $p < 0.001$ ) compared with staged THA patients. But no significant difference was found for complications (20, yes vs. 11, yes,  $p = 0.778$ ).

Table 3  
Clinical characteristics of patients

Groups	Total knee arthroplasty			Total hip arthroplasty			Pooled groups		
	Simultaneous (n = 789)	Staged (n = 391)	P Value	Simultaneous (n = 140)	Staged (n = 259)	P Value	Simultaneous (n = 929)	Staged (n = 650)	P Value
Complication, yes <sup>b</sup>	20(2.53%)	11(2.81%)	0.778	4(2.86%)	4(1.54%)	0.372	24(2.58%)	15(2.31%)	0.728
LOS, median(IQR) days <sup>a</sup>	9(8,11)	18(15,20)	< 0.000	10(8,11)	16(14,18)	< 0.000	9(8,11)	17(15,19)	< 0.000
Blood transfusion, yes <sup>b</sup>	302(38.28%)	32(8.18%)	< 0.000	51(36.43%)	36(13.90%)	< 0.000	353(37.99%)	68(10.46%)	< 0.000
LOS: length of stay.									

Staged THA patients had a lower incidence of blood transfusion(36, yes vs. 51, yes,  $p < 0.000$ ), and with a longer LOS(16 vs. 10 years,  $p < 0.001$ ) than those simultaneous THA patients. Same results as TKA groups for the count of complications(4, yes vs. 4, yes,  $p = 0.564$ ).

For patients pooled together, simultaneous groups with a higher incidence of blood transfusion(353, yes vs. 68, yes,  $p < 0.000$ ), had a shorter LOS(9 vs. 17 years,  $p < 0.001$ ). No statistical significance was found for complications either(24, yes vs. 15, yes,  $p = 0.728$ ).

## Patient Expenditures

The medical costs for each of the payment items were significantly different (all,  $p < 0.001$ ), and all costs were lower in the simultaneous bilateral TKA group than in the staged bilateral TKA group. As shown in Table 4. The total average medical expenses of simultaneous TKA were \$15,535.621 and staged TKA was \$16,747.192, with a difference value of \$1,211.571. For other payment items of medical costs, the highest cost was materials fees (\$12,037.664 vs \$12,245.999) and the lowest cost was nursing care fees (\$59.908 vs. \$88.479) (Table 4).

Table 4  
The medical costs for all payment items during hospitalization of patients

Groups	Total knee arthroplasty			Total hip arthroplasty		
	Simultaneous (n = 789)	Staged (n = 391)	P Value	Simultaneous (n = 140)	Staged (n = 259)	P Value
Total medical expenses	15535.621(12362.542,16450.131)	16747.192(14670.273,18036.289)	< 0.000	15046.21 (12838.230,17026.529)	16126.808 (14575.031,18867.963)	0.00
Bed fees	86.79 (70.430,110.215)	159.14 (135.140,188.940)	< 0.000	89.708 (77.919,112.135)	155.453 (134.332,178.648)	< 0.00
Fees of general therapy	98.863 (48.275,132.046)	145.204 (99.419,178.499)	< 0.000	98.51 (45.372,130.238)	123.518 (65.625,175.674)	0.00
Nursing care fees	59.908 (34.869,73.733)	88.479 (60.829,110.599)	< 0.000	59.908 (33.180,73.733)	96.774 (66.359,119.816)	< 0.00
Check-up and laboratory test fees	479.306 (432.796,1105.530)	1101.826 (915.061,1284.949)	< 0.000	473.859 (425.868,547.159)	958.183 (834.120,1128.402)	< 0.00
Surgical fees	1012.289 (432.796,1105.530)	1317.512 (902.458,1822.596)	< 0.000	1051.69 (486.655,1290.054)	1510.445 (1039.478,1858.065)	< 0.00
Charge for medical service	1194.599 (516.088,1325.127)	1576.166 (1147.235,2089.343)	< 0.000	1254.541 (555.353,1483.086)	1812.799 (1173.386,2128.578)	< 0.00
Drug fees	1311.049 (960.359,1797.792)	2161.687 (1631.350,2520.905)	< 0.000	1218.239 (889.334,1714.293)	1959.803 (1389.198,2623.393)	< 0.00
Materials fees	12037.664 (9439.459,13399.542)	12245.999 (9796.633,12702.510)	< 0.001	11794.072 (9676.080,14000.301)	11454.094 (10212.994,13680.321)	0.44
All values are in United States dollar(USD).						
All medical expenditures were presented as median (IQR) and compared by Mann-Whitney U test.						

The medical costs for almost all payment items of patients, with an exception of materials fees(\$11,794.072vs. \$11,454.094, p = 0.441), were a significantly difference in two sub-group of THA. As a whole, the total average medical cost of patients who underwent a simultaneous bilateral THA was significantly lower than in those who received a staged bilateral THA (\$15,046.210 vs. \$16,126.808, p = 0.003), with the difference value of \$1,080.598. The highest and the lowest cost were also materials fees and nursing care fees (\$59.908vs. \$96.774, p < 0.001) respectively(Table 4).

In general, the same results were presented by combining all patients who received TKA and THA together. As shown in Table 4. Costs of bed fees, fees of general therapy, nursing care fees, check-up, and laboratory test fees, surgical fees, charge for medical service, and drug fees were significantly lower compared with their counterparts (simultaneous bilateral total arthroplasty vs staged bilateral arthroplasty, all, p < 0.001). The comparison among materials fees has a different result with no statistical significance (\$11,860.321 vs. \$11,707.530, p = 0.736). Moreover, the total medical cost was significantly higher in patients who received a staged bilateral total arthroplasty than in those who underwent a simultaneous bilateral total arthroplasty (\$16,506.971 vs. \$15,467.561). Just like TKA and THA, the same trend for the highest and the lowest costs, they were materials fees and nursing care fees (\$59.908 vs. \$92.166 respectively(Table 4).

## Discussion

Despite bilateral knee and hip arthroplasty being frequently performed, most studies paid attention to clinic outcomes, and only a few studies have been published recently on this topic. However, previous studies have not compared costs about THA, to say nothing of comparing costs when pooled both THA and TKA patients[2, 7, 12]. In this study, we compared the cost of simultaneous and staged procedures among TKA, THA, and their combination groups, found a significant difference between the two procedures in three groups. Viewing the general conclusions as a whole, the results showed that almost all kinds of costs were higher in staged TKA, THA and combination simultaneous group.

Our results are consistent with previous studies, which have estimated the economy of simultaneous TKA or THA, compared with staged TKA or THA [2, 16–19]. A study from Taiwan demonstrated that all categories of medical costs, except for therapeutic procedure fees, were lower in the simultaneous TKA group[2]. However, a recent single-center study concluded that there was no significant difference in total hospital costs between two groups of TKA, and it

might be explained that the majority of their patients who received simultaneous TKA underwent patient rehabilitation (IPR) unit admission, and IPR costs were added for all patients discharged to IPR[7].

At the same time, many studies including our study have found a shorter LOS in simultaneous TKA or THA. Compared with simultaneous surgery, staged surgery will increase the number of anesthetics and hospital admissions, which usually means a longer LOS which has been regarded as a pivotal indicator of hospital efficiency and quality of health care[20]. Prolonged LOS will not only have a negative impact on health outcomes, causing iatrogenic illness easily, but also high hospital occupancy resulted in a resultant loss of efficiency and access, all of which would bring a marked increase in health expenses[21, 22]. And this might be explained the relationship between exceeding LOS with high cost, for long LOS unusually followed high costs[21–23].

This study found no significant difference in in-hospital complications, whether it was TKA, THA or pooled together. Previous studies about complications differ from each other. Kamath et al[1] did not find significant differences for complications between the simultaneous THA group and the staged THA group either. Seung-Chan Kim et al[12] found a lower incidence of postoperative prosthetic-related complications in the simultaneous THA group. When it turns to TKA, several studies reported a lower rate of complications in the simultaneous TKA group[14, 16, 19, 24, 25]. Whereas some studies have reported a higher rate of specific complications, such as venous thromboembolism (VTE)[7] and myocardial infarction (MI)[26] for the patients older than 65 years in the simultaneous TKA group. However, Sheth et al[27] considered that the differences in the baseline characteristics of the patients, surgeon's preference, and hospital characteristics may hamper the prior comparisons of complications between simultaneous TKA and staged TKA. They compared these two sub-groups by adjusting for these differences, founding no significant difference in complication rates between two sub-groups. Since the data of our study came from a single center, and the patient who underwent two procedures separated by the same surgeon was considered to have undergone staged bilateral TKA or THA, the inconsistency in-hospital characteristics, patient selection, surgeon skill, and surgeon preferences might be avoided. A meta-analysis[28] also proved no significant differences in complication rates. Moreover, studies that reported a higher rate of complication usually concentrated on certain complications, while our studies emphasized on the total number of in-hospital complications.

However, we also found a higher incidence of blood transfusion in the simultaneous groups compared with staged groups in all three groups. Sobh et al.[7], in a single institution of 562 patients, reported a significantly increased rate of blood transfusion with simultaneous TKA and the same result was found in using a large Canadian data set[13]. In a series of bilateral total knee or hip arthroplasty, performed at a staged interval, would have more time for hematopoiesis to replenish blood loss because of the first surgery[29]. Most of the staged patients in our study waited more than 6 months between procedures. Kamath et al.[1] found no blood transfusion in either group, but a higher blood loss in the staged group for THA. Because of the limitation of data, we could not analyze the volume of blood transfused. Further study needs to clarify the relationship between blood loss volume and different ways of procedures. And different blood transfusion practices and standards of reporting in different hospitals and surgeons would influence the final result, the interpretation of these results should be cautious.

Owing to the limitation of data and the aim of our study, other clinical outcomes were not included. Most clinical outcomes were better for simultaneous TKA and THA, and they indeed have some advantages, compared with staged TKA and THA, such as less length of stay in the hospital, lower costs, and no difference in complications which have been proved by this study. Accounting for a better surgical outcome, and relieving economic burden both for patients, families, and societies, we suggest that bilateral TKA and THA patients could be treated with a simultaneous TKA and THA rather than a staged TKA and THA. However, this procedure must be conducted very carefully, especially for elderly and high-risk patients.

Patients were older in the staged TKA and THA group than in the simultaneous TKA and THA group (Table 2), which is consistent with previous studies[1, 13]. Considering the operative risk, surgeons may prefer simultaneous procedures in younger and healthier patients, which might cause a selection bias and possibly result in better outcomes for simultaneous TKA and THA than staged TKA and THA. A recent study about the geriatric population reported that there was no association with any additional or significantly increased risk of morbidity or mortality compared to staged bilateral TKA[32]. Therefore, simultaneous TKA might be a safe and efficient choice for elderly people. While there needs more researches to remove this age bias and prove the suitability for older people, particularly in THA patients. An adequately powered randomized trial, which could overcome the selection bias inherent in this retrospective study design, would be a good choice for further clarification of outcomes.

These results may have important implications for the insurance department in the current health care environment. The cost of different surgeries for TKA and THA was different enough to warrant a separate classification for different procedures. Our results showed that staged bilateral TKA and THA have a greater financial cost than simultaneous bilateral TKA and THA, combined with the different clinical results of previous studies, suggesting that the two procedures should be classified separately for more accurate reimbursement. However, simultaneous bilateral TKA and THA and staged bilateral TKA and THA (calculate two surgical operations and reimbursed twice) are currently classified under the same Diagnosis Related Groups (DRGs), which means that they are reimbursed at the same level. Since medical insurance is the primary payer for patients in China[33], there needs reclassification of medical insurance items about these two procedures.

Limitations should be listed. Firstly, we investigated data from a single institution that performed a relatively high rate of TKA and THA, the universality of this study may be limited. However, this provided consistency in factors that might potentially affect clinical and financial outcomes, such as hospital characteristics, patient selection, surgeon skill, and surgeon preferences. Secondly, we did not analyze too many clinical outcomes because of the limitation of data, but our study aims to compare the medical expenditures and a fair number of previous studies have compared direct clinical outcomes. Thirdly, there might be a selection bias about the distribution of age, simultaneous procedures tending to be younger patients due to the surgeons' selection bias. But previous research has proved that simultaneous TKA might be a safe and efficient choice for elderly people. And despite being younger, the simultaneous groups experienced a higher rate of blood transfusion. Further researches should include an adequately powered multi-center randomized trial, which could overcome the selection bias of this retrospective study design.

In spite of these limitations, the strengths of our study including all kinds of hospitalization costs and many patients in both TKA and THA patients, and pooled patients together to prove the results. To our knowledge, this is the first study to evaluate the direct costs between two procedures both for TKA and THA and the whole patients in the same cohort. Further study needs to evaluate both the direct hospital costs and more clinical outcomes in the same cohort and an adequately powered randomized trial would be better.

## Conclusion

The three groups of patients between two sub-groups had similar results, and no significant differences were found in in-hospital complications. All kinds of medical expenses, except material fees, are lower for the simultaneous bilateral procedure, compared to a staged bilateral procedure whether it is TKA or THA or pooled groups. We also noted a significant difference in LOS, and the trends were the same as the costs. But simultaneous groups noted an increase in the risk of blood transfusion.

## Abbreviations

TKA: total knee arthroplasty; THA: total hip arthroplasty; TJA: total joint arthroplasty; LOS: length of stay; OA: osteoarthritis; RA: rheumatoid arthritis; HIS: hospital information system; ICD-10 International Classification of Diseases, 10th revision; CPI: Consumer Price Index; USD: US Dollars; IQR: interquartile ranges; IPR: patient rehabilitation; VTE: venous thromboembolism; MI: myocardial infarction; KSS: Knee Society Score; WOMAC: Western Ontario and McMaster Universities Arthritis Index; ROM: range of motion; LLD: lower leg-length discrepancy.

## Declarations

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### Availability of data and materials

The datasets supporting the conclusions of this article are included within the article/tables. The raw data can be requested from the corresponding author.

### Authors' contributions

All authors have contributed to this study. JF H and CH conceived and designed this study; JF H wrote the draft of this paper; CH for assisting in the collation and arrangement of the data presented; YZ L and CZ for writing assistance and proofreading the article; JL and YW for his guidance in statistical analysis in this study, and helped the interpretation of the data; CC L contributed to study coordination and was responsible for the English spelling and grammar, and YZ in charge of revision and guidance during the whole writing process of this thesis. All authors have participated in discussion, read and approved the final manuscript.

### Competing Interest

The authors declare that they have no conflict of interest.

### Consent to publish

Not Applicable

### Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee of the Affiliated Hospital of Qingdao University.

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