

# One-stage versus 2-stage bilateral total joint arthroplasty: a matched cohort study

Raghav Saini, MD  
James Powell, MD  
Rajrishi Sharma, MSc, MD  
Shannon Puloski, MD  
Saboura Mahdavi, MSc  
Christopher Smith, MBA  
Kelly Johnston, MD

Accepted Aug. 30, 2019

## Correspondence to:

S. Mahdavi  
Cumming School of Medicine  
University of Calgary  
Calgary AB T2N 4N1  
mahdavis@ucalgary.ca

DOI: 10.1503/cjs.001019

**Background:** Patients with bilateral end-stage hip or knee arthritis want to know if it is safe to have bilateral surgery under a single anesthetic, to restore their quality of life as quickly as possible. The purpose of this study was to assess if there is an increase in the rate of postoperative medical adverse events, length of stay (LOS), blood transfusion rate and 30-day readmission rate among patients who undergo 1-stage bilateral total hip arthroplasty (BTHA) and 1-stage bilateral total knee arthroplasty (BTKA) compared with patients who undergo 2-stage BTHA and BTKA.

**Methods:** Our study cohorts included patients who underwent BTHA and BTKA between Apr. 1, 2009, and Jan. 31, 2016, in Alberta, Canada. To minimize selection bias associated with our retrospective study design, we matched patients who underwent 1-stage BTHA and BTKA with patients with patients who underwent 2-stage BTHA and BTKA, respectively, for age, sex and number of presurgical risk factors using propensity score in a matching ratio of 1:1.

**Results:** Our study included 1645 patients who underwent BTHA and 4125 patients who underwent BTKA. We matched 195 patients who underwent 1-stage BTHA and 302 patients who underwent 1-stage BTKA with patients who underwent 2-stage BTHA and BTKA, respectively. There was no significant difference in postoperative medical adverse events between the 1-stage and 2-stage matched cohort groups for both BTHA (adjusted odds ratio [OR] 1.3, 95% confidence interval [CI] 0.3–4.9) and BTKA (adjusted OR 0.9, 95% CI 0.3–2.6). There was no difference in inpatient, 30- or 90-day mortality between the 2 groups for BTHA or BTKA. Patients who underwent 1-stage BTHA and BTKA had a shorter acute length of stay but increased total length of stay (acute care and rehabilitation unit) and were less likely to be discharged home postoperatively. One-stage BTHA and BTKA were associated with higher odds of blood transfusion than 2-stage BTHA and BTKA. The 30-day readmission rate was significantly lower for 1-stage BTHA than for the 2-stage BTHA matched cohort (adjusted OR 0.3, 95% CI 0.1–0.8), whereas there was no difference in the 30-day readmission rate (adjusted OR 0.6, 95% CI 0.2–1.7) between the 1-stage and 2-stage BTKA matched cohorts. Finally, operating room time was significantly lower for 1-stage BTHA (49.6 min less) and 1-stage BTKA (66.7 min less) than for the 2-stage arthroplasty procedures.

**Conclusion:** Healthy patients who undergo 1-stage BTHA and BTKA have postoperative medical complication rates comparable to those of patients who undergo 2-stage procedures with the additional benefits of a shorter acute length of stay, but they do have a higher risk of blood transfusion and are less likely to be discharged directly home from the acute care hospital. A multicentre randomized controlled trial on this topic is currently being conducted by the Canadian Arthroplasty Society.

**Contexte :** Les patients atteints d'arthrite bilatérale de la hanche ou du genou au stade terminal veulent savoir s'il est sécuritaire de subir une chirurgie bilatérale avec une seule anesthésie pour retrouver leur qualité de vie le plus rapidement possible. Le but de cette étude était de comparer le taux de complications postopératoires de nature médicale, la durée du séjour hospitalier, le taux de transfusions sanguines et le taux de réadmissions à 30 jours chez les patients selon que les arthroplasties totales de la hanche bilatérales (ATHB) et les arthroplasties totales du genou bilatérales (ATGB) se font en 1 étape ou en 2 étapes.

**Méthodes :** Les cohortes de notre étude incluaient des patients qui ont subi des ATHB et des ATGB entre le 1<sup>er</sup> avril 2009 et le 31 janvier 2016 en Alberta, au Canada. Pour réduire le biais de sélection associé à notre protocole d'étude rétrospective, nous avons assorti les patients soumis aux ATHB et aux ATGB en 1 étape à ceux qui les ont subies en 2 étapes, respectivement, selon l'âge, le sexe et le nombre de facteurs de risque préopératoires, avec score de propension et rapport 1:1.

**Résultats :** Notre étude a regroupé 1645 patients soumis à des ATHB et 4125 patients soumis à des ATGB. Nous avons assortis 195 patients soumis aux ATHB en 1 étape et 302 patients soumis aux ATGB en 1 étape avec des patients soumis à des ATHB et des ATGB en 2 étapes, respectivement. On n'a noté aucune différence significative quant aux complications postopératoires de nature médicale entre les groupes des cohortes assorties pour les interventions en 1 et en 2 étapes, tant avec les ATHB (rapport des cotes [RC] ajusté 1,3, intervalle de confiance [IC] de 95% 0,3–4,9), qu'avec les ATGB (RC ajusté 0,9, IC de 95% 0,3–2,6). Il n'y a pas eu de différences au plan de la mortalité à 30 jours ou à 90 jours chez les patients hospitalisés des 2 groupes avec les ATHB ou les ATGB. Les patients soumis aux ATHB et aux ATGB en 1 étape ont séjourné moins longtemps en soins actifs, mais la durée totale de leur séjour a été plus longue (soins actifs et réadaptation) et ils étaient moins susceptibles de retourner à la maison au moment de leur congé hospitalier après l'intervention. Les ATHB et les ATGB en 1 étape ont été associées à un risque plus grand de transfusions sanguines que les ATHB et les ATGB en 2 étapes. Le taux de réadmission à 30 jours a été significativement plus faible avec les ATHB en 1 étape que dans la cohorte assortie soumise aux ATHB en 2 étapes (RC ajusté 0,3, IC de 95% 0,1–0,8), tandis qu'il n'y a eu aucune différence au plan des taux de réadmission à 30 jours (RC ajusté 0,6, IC de 95% 0,2–1,7) entre les cohortes assorties soumises aux ATGB en 1 et 2 étapes. En terminant, le temps opératoire a été significativement plus bref avec les ATHB et les ATGB en 1 étape (respectivement 49,6 minutes et 66,7 minutes de moins) comparativement aux arthroplasties en 2 étapes.

**Conclusion :** Les patients en bonne santé qui subissent des ATHB et des ATGB en 1 étape ont des taux de complications postopératoires de nature médicale comparables à ceux qui les subissent en 2 étapes, avec l'avantage additionnel d'un séjour hospitalier plus bref en soins actifs; mais ils sont exposés à un risque plus grand de transfusions sanguines et sont moins susceptibles de retourner directement à la maison en quittant l'hôpital de soins actifs. La Société canadienne d'arthroplastie procède actuellement à un essai randomisé et contrôlé multicentrique à ce sujet.

**T**otal hip and knee arthroplasty are considered to be among the most successful surgical inventions, improving the quality of life of patients with end-stage osteoarthritis of the hip and knee, respectively.<sup>1,2</sup> Many patients with end-stage osteoarthritis have bilateral disease and could benefit from 1-stage bilateral total joint arthroplasty (BTJA). The benefits of 1-stage BTJA include a single surgery under anesthetic, the convenience for patients of a single rehabilitation period, and reduced costs to the health care system.<sup>3–7</sup> Many orthopedic surgeons are concerned that 1-stage BTJA may be associated with a greater risk of major complications and mortality than 2-stage BTJA and thus are reluctant to offer it.

The literature is not clear on the subject. There are many studies that suggest that 1-stage bilateral hip (BTHA) and knee (BTKA) arthroplasty have a higher mortality risk than 2-stage procedures.<sup>8–17</sup> A systematic review of 18 retrospective comparative studies demonstrated that there is a higher prevalence of postsurgical medical complications among patients who undergo 1-stage BTKA than among those who undergo 2-stage procedures.<sup>17</sup> On the contrary, the results from the New Zealand national joint registry and many other studies showed no statistically significant difference in the mortality rate and the rate of major complications for 1-stage BTHA and BTKA compared with 2-stage procedures.<sup>7,18–28</sup> Therefore, the decision to perform 1-stage BTJA or 2-stage BTJA remains controversial.

In this study we used data from a province-wide database to compare patients who underwent bilateral 1-stage BTHA and BTKA with patients who underwent 2-stage BTHA and BTKA, respectively. The purpose of this study was to ascertain if there is an increase in postoperative complications including mortality, hospital length of stay (LOS), blood transfusion and 30-day readmission rates among patients who undergo 1-stage bilateral procedures.

## METHODS

This study is a retrospective review of data in the Alberta Bone and Joint Health Data Repository held by the Alberta Bone and Joint Health Institute. Our study included all patients who underwent bilateral 1-stage or 2-stage BTHA or BTKA between Apr. 1, 2009, and Jan. 31, 2016. All patients who underwent revision hip or knee arthroplasty, hip resurfacing, hemiarthroplasty or unicompartmental knee arthroplasty were excluded from the study.

To minimize the effect of selection bias, we matched data for patients who underwent 1-stage BTHA with data for patients who underwent 2-stage BTHA for age, sex and number of presurgical risk factors using propensity score. We performed the same procedure for patients who underwent 1-stage and 2-stage BTKA.

Data on patient characteristics, presurgical risk factors, blood transfusions, hospital LOS and surgical time were

collected from electronic medical records, operating room information systems, the Discharge Abstract Database and the provincial surgical site infection surveillance system.

We compared the matched cohorts of patients who underwent 1-stage BTHA and 2-stage BTHA and the matched cohorts of patients who underwent 1-stage BTKA to 2-stage BTKA for various outcomes, including postoperative surgical complications, postoperative medical complications, mortality, blood transfusion, acute and total LOS, cut-close time, operating room time (time in to time out), likelihood of being discharged home, and 30-day readmission.

The 2-stage BTHA and BTKA cohorts included patients who underwent their second THA or TKA within 13 months. In the context of the wait lists inherent in a publicly funded health care system, more than 90% of bilateral procedures were completed within 13 months. Outcomes were analyzed by using the patient rather than the number of surgeries as the denominator. The age of patients for the 2-stage procedures was calculated as an average of the age of the patient at each of the 2 stages.

Reviews were used to identify the most commonly referenced comorbidities in the arthroplasty literature. The Alberta Bone and Joint Health Institute performed chart reviews to test the accuracy of the data capture in administrative data sets. From this list, Alberta's Hip and Knee Clinical Committee selected 11 risk factors as being clinically relevant to arthroplasty and having reasonable accuracy in terms of data capture (sensitivity > 80%). The resulting set of 11 presurgical risk factors was compared with the Charlson Comorbidity Index and the Elixhauser Comorbidity Index, and we found it to be superior in terms of capturing variability in outcomes (LOS, readmission, postoperative complications, change in physical function and death). The 11 presurgical risk factors were as follows: cardiac illness, chronic pulmonary condition, cancer, stroke, history of deep vein thrombosis or pulmonary embolism, chronic hepatic condition, chronic renal condition, diabetes with complications, obesity, dementia, and moderate or severe mental illness. Patients were grouped into 3 categories according to the number of preoperative risk factors they had: no risk factors, 1 risk factor and 2 or more risk factors.

Postoperative surgical complications included intraoperative fracture, postoperative fracture and postoperative dislocation. Postoperative medical adverse events included myocardial infarction, pulmonary embolus, deep vein thrombosis, cardiovascular accidents, ileus, gastrointestinal bleeding and pneumonia.

Acute LOS was calculated in days from the time of admission to discharge from the acute care hospital. For 2-stage BTJA, acute LOS was the sum of the acute LOS for each procedure. Total LOS was also calculated in days from the time of admission to the acute care hospital to discharge home. Therefore, total LOS included acute care and rehabilitation unit care. Operating room time was calculated in minutes from the time of entrance to the time of exit from the

operating room. For 2-stage BTHA and BTKA, operating room time was the sum of the in-out times for each procedure. Thirty-day readmission rate was calculated using readmissions for any reason within 30 days of surgical intervention.

### Statistical analysis

The Stata propensity score-matching procedure was used to find the matched cohort.<sup>29</sup> If a good match was not available for a patient, the patient was excluded from the matched cohort.<sup>30</sup> Continuous variables were summarized as means with standard deviation (SD), and categorical variables were expressed as numbers and percentages. We used *t* tests to compare continuous variables and Pearson  $\chi^2$  or Fisher exact tests to compare categorical variables. Multiple linear regression analyses were used to compare the matched cohorts of patients who underwent 1-stage and 2-stage BTHA and the matched cohorts of patients who underwent 1-stage and 2-stage BTKA with respect to acute and total LOS and operating room time. Multiple logistic regression analyses were conducted to compare the matched cohorts of patients who underwent 1-stage and 2-stage BTHA and the matched cohorts of patients who underwent 1-stage and 2-stage BTKA with respect to the rates of medical complications, surgical complications, mortality, 30-day readmission and transfusion. A *p* value less than 0.05 was deemed significant. All statistical analyses were performed with Stata version 13 software.

## RESULTS

Our study included 1645 patients who underwent BTHA, of whom 204 had 1-stage BTHA and 1441 had 2-stage BTHA. We were able to perform a closest perfect match for 195 patients in the 1-stage BTHA group in the ratio of 1:1 with patients in the 2-stage BTHA group. There were 4125 patients who had undergone BTKA, of whom 310 had 1-stage BTKA and 3815 had 2-stage BTKA. We were able to perform a closest perfect match for 302 patients in the 1-stage BTKA group in the ratio of 1:1 with patients in the 2-stage BTHA group.

The average age of patients undergoing 1-stage BTHA was 56.3 years whereas it was 64.1 years for patients undergoing 2-stage BTHA (Table 1). Male patients had 1-stage BTHA more frequently than 2-stage BTHA (49.0% v. 42.8%). One-stage BTHA was also offered more frequently to healthy patients than 2-stage BTHA: 65.2% of patients in the 1-stage BTHA group had no presurgical risk factors compared with 48.1% of patients in the 2-stage BTHA group. Therefore, it is evident that surgeons selected 1-stage BTHA more frequently for patients who were younger, male and healthier.

Similarly, 1-stage BTKA was performed more frequently in younger patients: the average age in the group undergoing 1-stage BTKA was 62.6 years whereas it was 66.0 years

in the group undergoing 2-stage BTKA (Table 1). Male patients had 1-stage BTKA more frequently than 2-stage BTKA (47.4% v. 39.7%). One-stage BTKA was also offered more frequently to healthy patients than 2-stage BTKA: 58.7% of patients in the 1-stage BTKA group had no presurgical risk factors compared with 41.6% of patients in the 2-stage BTKA group. Therefore, it is clear that surgeons selected 1-stage BTKA more frequently for patients who were younger, male and healthier.

The 1-stage groups were matched successfully to the 2-stage groups for both hip and knee arthroplasty procedures for age, sex and number of presurgical risk factors using propensity score (Table 2). There was no statistically significant difference in postoperative medical adverse events between the 1-stage and 2-stage matched cohort groups for both BTHA and BTKA (Table 3). There were no inpatient, 30-day or 90-day deaths among the 1-stage and 2-stage matched study groups for both BTHA and BTKA. However, compared with the matched 2-stage BTHA cohort, the 1-stage BTHA cohort had significantly lower odds of 30-day readmission (odds ratio [OR] 0.3, 95% confidence interval [CI] 0.1–0.8), higher odds of blood transfusion (OR 3.2, 95% CI 1.9–5.3), shorter acute LOS by 1.8 days, higher total LOS by 5.3 days and shorter operating room time by 49.6 minutes (Table 3 and Table 4). The 1-stage and 2-stage BTHA matched cohort groups had a similar likelihood of being discharged home.

Similarly, compared with the matched 2-stage BTKA cohort, the 1-stage BTKA cohort had significantly higher odds of blood transfusion (OR 4.3, 95% CI 2.8–6.8), shorter acute LOS by 1.9 days, longer total LOS by 2.1 days and shorter operating room time by 66.7 minutes (Table 3 and Table 4). In contrast, there was no statistically significant difference in 30-day readmission for the 1-stage and 2-stage BTKA matched cohorts (Table 3). Patients in the 1-stage BTKA were less likely to be discharged home postoperatively than those in the 2-stage BTKA cohort (Table 3).

The number of postsurgical complications was very low for both the BTHA and BTKA matched cohorts. The prevalence of such events was 0.5% in both the 1-stage and 2-stage BTHA matched cohorts ( $p = 1.0$ ). There were no such events in the 1-stage and 2-stage BTKA matched cohorts.

## DISCUSSION

Many surgeons are reluctant to offer 1-stage BTJA to patients with arthritis because of concerns about a higher risk of postoperative medical complications with this option. We found no difference in the rate of postoperative medical complications (myocardial infarction, pulmonary embolus, deep vein thrombosis, cardiovascular accidents, ileus, gastrointestinal bleeding and pneumonia)

**Table 1. Characteristics of bilateral total joint arthroplasty cohorts**

Characteristic	Bilateral total hip arthroplasty			Bilateral total knee arthroplasty		
	1-stage <i>n</i> = 204	2-stage <i>n</i> = 1441	<i>p</i> value	1-stage <i>n</i> = 310	2-stage <i>n</i> = 3815	<i>p</i> value
Age, yr, mean ± SD	56.3 ± 12.1	64.1 ± 11.1	< 0.001	62.6 ± 8.9	66.0 ± 9.0	< 0.001
Male, no. (%)	100 (49.0)	617 (42.8)	0.095	147 (47.4)	1513 (39.7)	0.007
Presurgical risk factor group, no. (%)						
0	133 (65.2)	693 (48.1)	< 0.001	182 (58.7)	1586 (41.6)	< 0.001
1	36 (17.7)	389 (27.0)		76 (24.5)	1027 (26.9)	
≥ 2	35 (17.2)	359 (24.9)		52 (16.8)	1202 (31.5)	

BTHA = bilateral total hip arthroplasty; BTKA = bilateral total knee arthroplasty.

**Table 2. Characteristics of the bilateral total joint arthroplasty matched cohorts**

Characteristic	Bilateral total hip arthroplasty			Bilateral total knee arthroplasty		
	1-stage <i>n</i> = 195	2-stage <i>n</i> = 195	<i>p</i> value	1-stage <i>n</i> = 302	2-stage <i>n</i> = 302	<i>p</i> value
Age, yr, mean ± SD	56.2 ± 12.0	56.6 ± 11.1	0.70	62.5 ± 8.9	62.4 ± 8.8	
Male, no. (%)	99 (50.8)	99 (50.8)	1.00	142 (47.0)	142 (47.0)	1.00
Presurgical risk factor group, no. (%)						
0	127 (65.1)	128 (65.6)	0.99	178 (58.9)	177 (58.6)	1.00
1	34 (17.4)	34 (17.4)		74 (24.5)	75 (24.8)	
≥ 2	34 (17.4)	33 (16.9)		50 (16.6)	50 (16.6)	

BTHA = bilateral total hip arthroplasty; BTKA = bilateral total knee arthroplasty.

**Table 3. Adjusted outcomes for the bilateral total joint arthroplasty matched cohort using multiple logistic regression**

Adjusted outcome*	1-stage BTHA v. 2-stage BTHA		1-stage BTKA v. 2-stage BTKA	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Postoperative medical adverse event	1.3 (0.3 to 4.9)	0.74	0.9 (0.3 to 2.6)	0.79
Transfusion	3.2 (1.9 to 5.3)	< 0.001	4.3 (2.8 to 6.8)	< 0.001
Readmission within 30 d after surgery	0.3 (0.1 to 0.8)	0.015	0.6 (0.2 to 1.7)	0.31
Discharge to home with or without support	0.83 (0.49 to 1.43)	0.51	0.56 (0.35 to 0.90)	0.015

BTHA = bilateral total hip arthroplasty; BTKA = bilateral total knee arthroplasty; CI = confidence interval; OR = odds ratio.  
\*Adjusted by age, sex and presurgical risk factor group.

**Table 4. Adjusted outcomes for the bilateral total joint arthroplasty matched cohorts using multiple linear regression**

Adjusted outcome*	1-stage BTHA outcome – 2-stage BTHA outcome		1-stage BTKA outcome – 2-stage BTKA outcome	
	Mean difference (95% CI)	<i>p</i> value	Mean difference (95% CI)	<i>p</i> value
Acute LOS, d	-1.8 (-2.4 to -1.1)	< 0.001	-1.9 (-2.4 to -1.3)	< 0.001
Total LOS, d	5.3 (3.2 to 7.4)	< 0.001	2.1 (0.4 to 3.7)	0.015
Cut–close time, min	-12.3 (-21.7 to -2.9)	0.010	-36.8 (-43.7 to -29.9)	< 0.001
Operating room time, min	-49.6 (-60.5 to -38.7)	< 0.001	-66.7 (-74.2 to -59.2)	< 0.001

BTHA = bilateral total hip arthroplasty; BTKA = bilateral total knee arthroplasty; CI = confidence interval; LOS = length of stay.  
\*Adjusted by age, sex and presurgical risk factor group.

or mortality and a significantly lower 30-day readmission rate for the 1-stage BTHA matched cohort compared with the 2-stage BTHA cohort ( $p = 0.015$ ). Similarly, the 1-stage BTKA matched cohort had rates of medical complications, mortality and 30-day readmission that were similar to those of the 2-stage BTKA matched cohort.

These findings suggest that healthy patients with no presurgical risk factors can be treated with 1-stage, as opposed to 2-stage, bilateral joint arthroplasty without being exposed to a higher risk of medical complications or mortality. However, we cannot confidently draw similar conclusions for patients with 1 or more presurgical risk factors as the number of such patients was small in our matched cohorts.

The results of our study are in agreement with meta-analyses of the literature.<sup>7,18–28</sup> A study by Shao and colleagues concluded that 1-stage BTHA is superior to 2-stage BTHA in terms of major systemic complications, deep venous thrombosis, LOS and surgical time.<sup>27</sup> A similar meta-analysis of 18 studies compared 1-stage and 2-stage BTKA and concluded that the rates of medical complications are similar in the 2 groups.<sup>28</sup> However, the results of our study are in contrast to those of many of the earlier studies, including a systematic review of retrospective studies.<sup>8–17</sup> Our study is methodologically stronger, as we compared the results for matched cohorts, reducing selection bias in our study population.

We also found a statistically significant shorter acute LOS and more efficient use of operating room times for 1-stage BTHA and BTKA. The acute LOS in the 1-stage BTHA and BTKA groups was 1.8 and 1.9 days shorter,

respectively, than that of the corresponding 2-stage groups. Many other studies of bilateral arthroplasty have also found a reduced LOS with 1-stage BTJA.<sup>3–7,18–28</sup> Acute care hospital stay is a major contributor to the cost of total hip or knee arthroplasty. Moreover, 1-stage BTJA may reduce societal costs to the health care system, as it is projected to reduce the overall cost of care by 18%–36%.<sup>13</sup> These data are tempered by the finding that total LOS was significantly higher for the 1-stage arthroplasty groups and that these patients were less likely to be discharged home from the acute care hospital. Our data show that 1-stage BTJA in healthy patients helps to reduce acute care costs while maintaining patient safety. An additional societal benefit is the increased quality of life and productivity experienced by patients treated for bilateral disease with a single surgical event.

This study shows that there was a significantly higher odds of transfusion in patients who underwent 1-stage BTJA (hip or knee) than in patients who underwent 2-stage BTJA (hip or knee), which is consistent with the findings of many other publications.<sup>2,3,10–23,25–28</sup> Higher risk of allogenic blood transfusion is an important consideration, as such transfusions can transmit infectious agents and modulate the immune system to increase the risk of infection. In addition, it is an important consideration for patients who have religious or personal reasons for avoiding blood transfusion and for patients whose starting hemoglobin level remains very low even with iron or folic acid supplementation. In our study, transfusion rates may have been higher than they are today, as tranexamic acid was not being used routinely during arthroplasty procedures in the early years

of our study period. This is no longer the case. A study by Fu and colleagues has also shown that the use of blood transfusion has decreased over time in both groups with the adoption of more stringent transfusion policies whereby patients are treated symptomatically rather than automatically being given blood transfusions if their hemoglobin level drops below approximately 8 g/dL.<sup>17</sup> We recommend that patients who are waiting for 1-stage BTJA be treated with oral iron and folic acid supplements to maximize their preoperative hemoglobin and that tranexamic acid be used routinely during the operative procedure.

In our study, healthy patients with no presurgical risk factors constituted approximately 50% and 43% of the patients who underwent BTHA and BTKA, respectively. This patient cohort constitutes a substantial fraction of the population needing BTHA and BTKA procedures and they can be offered 1-stage BTHA or BTKA, which gives them the advantage of a shorter LOS and a single rehabilitation period without compromising their safety.

### Limitations

A potential limitation of this study is its retrospective study design, which can introduce bias. However, we attempted to reduce selection bias by matching the 1-stage and 2-stage groups for the important variables that could have affected the outcomes by which we compared the 2 groups. A bias that could not be controlled in this retrospective study was the automatic exclusion of patients who intended to have a bilateral staged arthroplasty but who declined to have surgery on the second side or who died after undergoing the first procedure. As pointed out in other papers, this can lead to underreporting of adverse events in the 2-stage bilateral group.<sup>31,32</sup> With our administrative database, we were unable to separate these patients from patients who presented for a unilateral joint replacement. Although this is a definite weakness in our study design, underreporting complications in the group who underwent what is considered the most conservative and safe approach only set the bar higher for the 1-stage bilateral cohort when we compared the 2 groups for medical and surgical complications, mortality and blood transfusions. This same type of bias may be at play in the significantly higher total LOS reported in this study for the 1-stage bilateral cohort as patients who had a poor experience and long hospital stays after arthroplasty on the first side may have declined to have surgery on the second side and been excluded from the analysis. This paper only compares patients who completed bilateral treatment for their joint disease.

### CONCLUSION

The retrospective design of our study means that there is a risk that medical complications and mortality were underreported among the patients who underwent 1-stage

BTJA. Otherwise, we could have concluded that 1-stage BTJA can be offered to healthy patients with no presurgical risk factors who have bilateral end-stage arthritis without exposing them to a higher rate of postoperative medical complications or mortality. A single operative event to treat bilateral hip or knee osteoarthritis, even in healthy patients, does increase the risk of blood transfusion and this must be considered before it is offered to all healthy patients with end-stage bilateral osteoarthritis of the hip or knee. Our matched cohort findings add to the literature on this topic, which is dominated by registry and purely retrospective data. We recommend a prospective, randomized study and look forward to one being conducted by the Canadian Arthroplasty Society.

**Acknowledgement:** The authors thank Sophie Ghashang Piroozfar for her help in addressing the reviewers' comments.

**Affiliations:** From the Cumming School of Medicine, University of Calgary, Calgary, Alta. (Saini, Powell, Sharma, Puloski, Mahdavi, Johnston); and the Alberta Bone and Joint Health Institute, Calgary, Alta. (Smith).

**Competing interests:** R. Sharma reports receiving consulting fees from Depuy Synthes, Zimmer Biomet, Stryker and Mizuho OSI, outside the submitted work. C. Smith reports receiving an unrestricted research grant from Smith & Nephew for a research study unrelated to the submitted work.

**Contributors:** R. Saini, J. Powell, R. Sharma, S. Mahdavi and K. Johnston designed the study. C. Smith and K. Johnston acquired the data, which R. Sharma, S. Puloski and K. Johnston analyzed. R. Saini, C. Smith and K. Johnston wrote the article, which J. Powell, R. Sharma, S. Puloski, S. Mahdavi, C. Smith and K. Johnston critically reviewed. All authors approved the final article for publication.

### References

- Harris WH. The first 50 years of total hip arthroplasty. *Clin Orthop Relat Res* 2009;467:28-31.
- Ritter MA, Harty LD. Debate: simultaneous bilateral knee replacements: the outcomes justify its use. *Clin Orthop Relat Res* 2004;428:84-6.
- Parvizi J, David T, Sheikh E, et al. Bilateral total hip arthroplasty: one-stage versus two-stage procedures. *Clin Orthop Relat Res* 2006;(453):137-41.
- Alfaro-Adrian J, Bayona F, Rech JA, et al. One- or two-stage bilateral total hip replacement. *J Arthroplasty* 1999;14:439-45.
- Reuben JD, Meyers SJ, Cox DD, et al. Cost comparison between bilateral simultaneous, staged and unilateral total joint arthroplasty. *J Arthroplasty* 1998;13:172-9.
- Liu TK, Chen SH. Simultaneous bilateral total knee arthroplasty in a single procedure. *Int Orthop* 1998;22:390-3.
- Romagnoli S, Zacchetti S, Peazzo P, et al. Simultaneous bilateral total hip arthroplasties do not lead to higher complication or allogeneic transfusion rates compared to unilateral procedures. *Int Orthop* 2013;37:2125-30.
- Berend KR, Lombardi AV, Adams JB. Simultaneous vs staged cementless bilateral total hip arthroplasty perioperative risk comparison. *J Arthroplasty* 2007;22:111-5.
- Ritter MA, Stringer EA. Bilateral total hip arthroplasty: a single procedure. *Clin Orthop Relat Res* 1980;149:185-9.
- Parvizi J, Thomas J, Trousdale RT, et al. Thirty-day mortality after total knee arthroplasty. *J Bone Joint Surg* 2001;83:1157-61.
- Oaks DA, Hanssen AD. Bilateral total knee replacement using the same anesthetic is not justified by assessment of the risks. *Clin Orthop Relat Res* 2004;428:87-91.

12. Leonard L, Williamson DM, Ivory JP, et al. An evaluation of the safety and efficacy of simultaneous bilateral total knee arthroplasty. *J Arthroplasty* 2003;18:972-8.
13. Memtsoudis SG, Ma Y, González Della Valle A, et al. Perioperative outcomes after unilateral and bilateral total knee arthroplasty. *Anesthesiology* 2009;111:1206-16.
14. Mangaleshkar SR, Prasad PS, Chugh S, et al. Staged bilateral total knee replacement — a safer approach in older patients. *Knee* 2001;8:207-11.
15. Ritter M, Mamlin LA, Melfi CA, et al. Outcome implications for the timing of bilateral total knee arthroplasties. *Clin Orthop Relat Res* 1997;345:99-105.
16. Stefánsdóttir A, Lidgren L, Robertsson O. Higher early mortality with simultaneous rather than staged bilateral TKAs: results from the Swedish Knee Arthroplasty Register. *Clin Orthop Relat Res* 2008;466:3066-70.
17. Fu D, Li G, Chen K, et al. Comparison of clinical outcome between simultaneous bilateral and staged-bilateral total knee arthroplasty: a systematic review of retrospective studies. *J Arthroplasty* 2013;28:1141-7.
18. Hooper GJ, Hooper NM, Rothwell AG, et al. Bilateral total joint arthroplasty: the early results from the New Zealand National Joint Registry. *J Arthroplasty* 2009;24:1174-7.
19. Trojani C, d'Ollonne T, Saragaglia D, et al. One-stage bilateral total hip arthroplasty: functional outcomes and complications in 112 patients. *Orthop Traumatol Surg Res* 2012;98:S1203-3.
20. Aghayev E, Beck A, Staub LP, et al. Simultaneous bilateral hip replacement reveals superior outcome and fewer complications than two stage procedures: a prospective study including 1819 patients and 5801 followups from a total joint replacement registry. *BMC Musculoskelet Disord* 2010;11:245.
21. Lindberg-Larsen M, Joergensen CC, Husted H, et al. Simultaneous and staged bilateral total hip arthroplasty: a Danish nationwide study. *Arch Orthop Trauma Surg* 2013;133:1601-5.
22. Tsiridis E, Pavlou G, Charity J, et al. The safety and efficacy of bilateral simultaneous total hip replacement: an analysis of 2063 cases. *J Bone Joint Surg Br* 2008;90:1005-12.
23. Haverkamp D, Bekerom M, Harmse I, et al. One stage bilateral total hip arthroplasty, is it safe? a meta-analysis. *Hip Int* 2010;20:440-6.
24. Spicer E, Thomas GR, Rumble EJ. Comparison of the major intra-operative and postoperative complications between unilateral and sequential bilateral total knee arthroplasty in a high-volume community hospital. *Can J Surg* 2013;56:311-17.
25. Kim YH, Choi YW, Kim JS. Simultaneous bilateral sequential total knee replacement is as safe as unilateral total knee replacement. *J Bone Joint Surg Br* 2009;91:316-20.
26. Jain S, Wasnik S, Mittal A, et al. Simultaneous bilateral total knee replacement: a prospective study of 150 patients. *J Orthop Surg (Hong Kong)* 2013;21:19-22.
27. Shao H, Chen CL, Maltenfort MG, et al. bilateral total hip arthroplasty: 1-stage or 2-stage? A meta-analysis. *J Arthroplasty* 2017;32:689-95.
28. Hussain N, Chien T, Hussain F, et al. Simultaneous versus staged bilateral total knee arthroplasty: a meta-analysis evaluating mortality, peri-operative complications and infection rates. *HSS J* 2013;9:50-9.
29. Austin PC. An introduction to propensity score methods for reducing the effects of confounding in observational studies. *Multivariate Behav Res* 2011;46:399-424.
30. Rosenbaum PR, Rubin DB. The central role of the propensity score in observational studies for causal effects. *Biometrika* 1983;79:516-24.
31. Bohm ER, Molodianovitch K, Dragan A. Outcomes of unilateral and bilateral total knee arthroplasty in 238,373 patients. *Acta Orthop* 2016;87:24-30.
32. Meehan JP, Danielsen B, Tancredi DJ, et al. A population-based comparison of the incidence of adverse outcomes after simultaneous-bilateral and staged-bilateral total knee arthroplasty. *J Bone Joint Surg Am* 2011;93:2203-13.