



Do older patients fare worse following unilateral or single stage bilateral total knee arthroplasty?

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Abstract

Introduction The safety and benefits of single stage bilateral total knee arthroplasty (SSBTKA) among older patients as compared to unilateral TKA remains controversial. This study aimed to evaluate the influence of age and comorbidities on complications and early outcomes for unilateral and BTKA in patients over and under 70 years of age.

Materials and methods This prospective study compared postoperative complications and early patient-reported outcomes at 6 weeks of 142 unilateral TKA patients ($N=75, \leq 70$; $N=67, > 70$) and 89 SSBTKA patients ($N=48, \leq 70$; $N=41, > 70$). Patients completed the KOOS JR and PROMIS Global Mental (GMH) and Global Physical Health (GPH) surveys. Knee Society Scores for Knee (KSS-K) and Function (KSS-F) were completed in the clinic. Parametric tests were performed for comparisons of unilateral and BTKA outcomes and complications for patients over and under 70.

Results While patient demographics were similar, patients > 70 had more comorbidities than patients ≤ 70 ($p < 0.004$). There were no significant differences in postoperative complications or readmissions between age groups or procedures. Unilateral TKA patients > 70 had significantly lower pre- ($p < 0.001$) and post-operative ($p = 0.011$) KSS-F scores compared to those ≤ 70 . SSBTKA patients > 70 had significantly higher preoperative GMH ($p = 0.029$), postoperative KSS-K ($p = 0.027$), KOOS JR scores ($p = 0.039$) and satisfaction ($p = 0.048$) compared to those ≤ 70 .

Conclusion Age did not influence the risk of early postoperative complications. Additionally, the greater improvements in KOOS JR and higher patient satisfaction for SSBTKA patients > 70 suggests that SSBTKA may meet elderly patient expectations and should not necessarily be discouraged due to safety concerns.

Keywords Elderly · Outcomes · Complications · Single stage bilateral · Safety · Satisfaction

Introduction

As the population ages, the need for total knee arthroplasty (TKA) will continue to increase [1]. Fortunately, TKA is a safe and effective procedure for decreasing symptoms associated with osteoarthritis and improving quality of life [2–4]. For patients presenting with bilateral symptoms, however, the best treatment option remains unclear. Performing a SSBTKA can reduce overall hospital stay, reduce overall

cost and involves only one anesthetic event compared to staged bilateral TKA [5–8]. Despite these advantages, many surgeons discourage patients from undergoing SSBTKA as previous research has reported higher complication rates compared to both unilateral and staged bilateral procedures [7, 9–15]. When offered, SSBTKA is often limited to a highly selective patient cohort [16].

Surgeons performing SSBTKA commonly select younger patients with few comorbidities. Careful selection of patients appropriate for SSBTKA is well supported as age and the number of comorbidities have been shown to be most predictive of major complications and mortality [16–18]. The influence of age and comorbidities has been reported to be more pronounced in patients suffering from bilateral osteoarthritis, as the functional deficits faced by these patients tend to increase the risk of specific comorbidities, such as cardiovascular and pulmonary conditions [16, 17]. These risk factors have further justified the exclusion of elderly

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patients from undergoing SSBTKA, even when significant bilateral symptoms are present. Unfortunately, previous literature has included heterogeneous surgical approaches and patient management strategies [9, 19, 20], and many are unable to isolate the influence of age and comorbidities on postoperative complications. Understanding the influence of age and comorbidities on complications associated with SSBTKA will allow surgeons to choose the most safe and efficient treatment for patients with bilateral symptoms. Therefore, the primary objective of this study was to compare the incidence of early complications following unilateral and SSBTKA performed in patients younger and older than 70. Secondly, this study (1) compared comorbidities of each group and the influence on complications and (2) evaluated early functional outcomes and patient satisfaction between patients ≤ 70 and > 70 for both unilateral and SSBTKA.

Materials and methods

These data were prospectively collected as part of an ongoing, institutional review board approved joint registry at the current study site between April 2019 and January 2021. Patients meeting the clinical and radiographic criteria for end-stage knee osteoarthritis and scheduled for surgery were consented to be a part of the registry. Patients having symptomatic bilateral osteoarthritis were offered SSBTKA. The current study site does not exclude patients from consideration of either unilateral TKA or SSBTKA based on demographic or comorbidity status. Patients were only excluded from any surgical consideration if they had an open or poorly healing wound, active osteomyelitis, systemic infection, bacteremia or sepsis currently under treatment. Patients with a history of osteomyelitis were required to be asymptomatic following cessation of antibiotic treatment for one year prior to surgery. Patients were excluded if they suffered a myocardial infarction, cerebrovascular accident or required any cardiovascular surgical procedure within three months prior to surgery. Patients were also excluded if they had any unstable cardiovascular or cardiopulmonary condition or had any active or uncontrolled chronic gastrointestinal bleeding. Patients who required revascularization procedures of the lower extremities within three months of intended joint replacement were also excluded. The patient's primary care physician performed standard preoperative medical clearance for surgery, with specific medical concerns evaluated by medical specialists when required. All patients were screened by a core group of experienced anesthesiologists as part of the Perioperative Surgical Home initiative put forth by the American Society of Anesthesiologists (ASA) [21].

A single, fellowship-trained arthroplasty surgeon at a community hospital performed all clinical evaluations and

surgeries. All TKAs were performed via medial parapatellar approach under general anesthesia with an adductor canal regional nerve block. Blood management strategies included the use of a tourniquet and intravenous tranexamic acid prior to incision and before closure of the arthrotomy. Upon wound closure, each patient was given dexamethasone (4 mg) intravenously to control postoperative nausea. All SSBTKAs were performed by the same surgeon under a single anesthetic event. By established protocol, the left knee was performed first. Following wound closure and dressing application of the left knee, the right knee was prepared and performed using a separate sterile instrument set. The time required for preparation of the right knee and initial incision was approximately 30 min following dressing application of the left knee. Postoperative pain management included primarily acetaminophen with oral narcotics provided only upon patient request for breakthrough pain. Postoperative nausea was symptomatically treated with anti-emetics.

As part of the standard of care, all patients completed the knee disability and osteoarthritis outcome joint replacement survey (KOOS JR) and the patient-reported outcomes measurement information system (PROMIS) Global Mental (GMH) and Global Physical health (GPH) which were collected preoperatively and six weeks following surgery. The change in patient-reported outcome measures were calculated as the preoperative score subtracted from the postoperative score, with a positive number indicating an increase in health. If the patient was unwilling or unable to attend an in-person office visit due to the COVID-19 pandemic, a telehealth option was offered, and surveys were collected via phone.

In addition to patient-reported outcomes, collected data included a comprehensive list of comorbidities based on the Charlson Comorbidity Index (CCI). Comorbidities were collected by ICD-10 codes as well as manual chart review. These data were reported as the composite CCI score and the unweighted, total number of comorbidities for each age group and procedure. The assigned ASA was also collected and grouped by ≤ 2 and ≥ 3 . Preoperative hemoglobin was used to classify anemia status based on the World Health Organization criteria, including less than 12 g/dL for females and 13 g/dL for males [22]. Pre- and post-operative clinical data were also collected, including the Knee Society Knee Score (KSS-K) and Function Score (KSS-F). Postoperative complications included any superficial or periprosthetic infection, systemic complications (deep vein thrombosis or pulmonary embolism; DVT or PE, respectively), emergency room visits and hospital readmissions within 90 days from surgery.

For data analysis, the average age of the patient cohort was approximately 70 years old, therefore, age was grouped by ≤ 70 and > 70 . Descriptive statistics, including mean, standard deviation and frequency, were created for patient

demographics for each age group and procedure. Independent *t*-tests and Chi-square tests were performed to determine differences in patient specific variables between (1) age groups for unilateral and SSBTKA and (2) unilateral and SSBTKA by age group.

Results

Patient demographics

Overall, 231 patients were included in data analysis, with 142 unilateral TKAs ($N=75, \leq 70; N=67, > 70$) and 89 SSBTKAs ($N=48, \leq 70; N=41, > 70$). In the unilateral TKA group, patients > 70 had significantly lower body mass index (BMI) ($p=0.013$), higher CCI ($p=0.003$) and

greater total number of comorbidities ($p=0.004$) compared to patients ≤ 70 (Table 1). A significantly greater percentage of patients > 70 had undiagnosed preoperative anemia ($p=0.026$) compared to patients ≤ 70 , however, there was no difference in postoperative complications (Table 2). In the bilateral group, patients > 70 had a higher CCI ($p < 0.001$), greater total number of comorbidities ($p < 0.001$) and a greater percentage of patients with undiagnosed preoperative anemia ($p=0.049$) compared to patients ≤ 70 , however, there was no difference in postoperative complications. When comparing each procedure between age groups, there were no significant differences in patient demographics between unilateral and SSBTKA patients ≤ 70 , however, amongst patients > 70 , SSBTKA patients trended toward a slightly higher rate of readmissions ($p=0.068$) and transfusions ($p=0.068$) compared to unilateral TKA patients. Specific

Table 1 Comparison of patient demographics for unilateral and single-staged bilateral patients between age groups—mean (SD)/freq (%)

	Unilateral		<i>p</i> value	Bilateral		<i>p</i> value	Uni vs Bilateral	
	≤ 70	> 70		≤ 70	> 70		≤ 70	> 70
<i>N</i>	75	67		48	41			
Age	61.8 (7.5)	75.8 (4.1)	< 0.001	63.9 (5.5)	75.8 (4.3)	< 0.001	0.104	0.944
Body Mass Index	30.6 (5.3)	28.6 (5.1)	0.013	30.8 (5.7)	29.1 (4.2)	0.132	0.861	0.432
Gender (male)	34 (45.3%)	40 (59.7%)	0.061	16 (33.3%)	18 (43.9%)	0.211	0.128	0.081
CCI	1.64 (1.8)	2.67 (2.2)	0.003	1.35 (0.9)	2.83 (1.7)	< 0.001	0.308	0.697
No. of comorbidities	1.4 (1.4)	2.1 (1.5)	0.004	1.3 (0.8)	2.1 (1.0)	< 0.001	0.511	0.892
ASA > 2	35 (53.8%)	45 (68.2%)	0.120	28 (58.3%)	29 (70.7%)	0.160	0.518	0.478
Ethnicity			0.194			0.200	0.038	0.743
Asian	29 (38.7%)	38 (56.7%)		29 (60.4%)	25 (61.0%)			
White	30 (40.0%)	19 (28.4%)		8 (16.7%)	12 (29.3%)			
NH/PI	9 (12.0%)	5 (7.5%)		5 (10.4%)	3 (7.3%)			
Other	7 (9.3%)	5 (7.5%)		6 (12.5%)	1 (2.4%)			
Diabetes	30 (40.0%)	29 (43.3%)	0.411	21 (43.8%)	13 (31.7%)	0.172	0.411	0.16
Pre-WHO anemia	4 (6.0%)	12 (18.5%)	0.026	6 (12.8%)	12 (29.3%)	0.049	0.177	0.146

Significant *p* values are shown in bold for easier identification

N number of patients, *SD* standard deviation, *Freq* frequency, *CCI* Charlson Comorbidity Index, *ASA* American Society of Anesthesiology

Pre-WHO anemia=Pre-operative hemoglobin; used to classify anemia status based on the World Health Organization criteria of < 12 g/dL for females and 13 g/dL for males

Table 2 Comparison of complications for unilateral and single-staged bilateral patients between age groups—freq (%)

	Unilateral			Bilateral			Uni vs Bilateral	
	≤ 70	> 70	<i>p</i> value	≤ 70	> 70	<i>p</i> value	≤ 70	> 70
Transfusions	1 (1.3%)	1 (1.5%)	0.723	1 (2.1%)	4 (9.8%)	0.135	0.63	0.068
Emergency Room Visits	4 (5.3%)	3 (4.5%)	0.563	0 (0.0%)	2 (4.9%)	0.290	0.134	0.631
Readmission	3 (4.0%)	1 (1.5%)	0.354	3 (6.3%)	4 (9.8%)	0.411	0.435	0.068
Pulmonary Embolism	0 (0.0%)	0 (0.0%)	–	2 (4.2%)	0 (0.0%)	0.288	0.150	–
Deep Vein Thrombosis	1 (1.3%)	0 (0.0%)	0.528	1 (2.1%)	1 (2.4%)	0.712	0.630	0.380
Wound Infection	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–	–	–
Periprosthetic Infections	0 (0.0%)	0 (0.0%)	–	0 (0.0%)	0 (0.0%)	–	–	–

Freq frequency

reasons for readmission and emergency department visits are presented in Table 3.

Individual comorbidities

The frequency for each component of the CCI is presented in Table 4. In the unilateral group, only hypertension occurred at a higher percentage in patients > 70 compared to patients ≤ 70 ($p=0.012$). In the SSBTKA group, patients > 70 had a higher percentage of cerebrovascular accidents or transient ischemic disease ($p=0.008$), renal disease ($p<0.001$) and all types of cancer ($p=0.025$). When comparing each procedure between age groups, there was no significant difference in comorbidities between unilateral and SSBTKA patients ≤ 70. Amongst patients > 70, only renal disease occurred more frequently in SSBTKA patients compared to unilateral TKA patients ($p=0.011$).

Clinic and patient-reported outcomes

Clinical and patient-reported outcomes are presented in Table 5. In the unilateral comparison, patients > 70 had significantly lower KSS-F both pre- ($p<0.001$) and postoperatively ($p=0.011$) compared to patients ≤ 70. Patient-reported outcomes (GPH and GMH) and the change in all measurements were not significantly different. In the bilateral group, patients > 70 had significantly higher preoperative GMH ($p=0.029$) and higher postoperative KSS-K

($p=0.027$) and KOOS JR ($p=0.039$) scores compared to patients ≤ 70. Although there was lower improvement in KSS-F ($p=0.004$), patients > 70 had greater improvement in KOOS JR scores ($p=0.023$) and greater patient satisfaction ($p=0.048$) compared to patients ≤ 70. When comparing each procedure between age groups, patients ≤ 70 undergoing BTKA had lower preoperative KSS-F ($p=0.002$) but greater improvement in KSS-F ($p<0.001$) and GPH ($p=0.020$) compared to unilateral TKA patients. Patients > 70 undergoing SSBTKA had higher postoperative KSS-K ($p=0.003$) and greater patient satisfaction ($p=0.018$) compared to unilateral TKA patients.

Discussion

Single stage BTKA has been shown to be a safe and effective procedure; however, due to the perceived increased risk of postoperative complications [23–25], elderly patients may be discouraged from undergoing SSBTKA. Therefore, this study compared the incidence of early postoperative complications for patients > 70 and ≤ 70, undergoing either unilateral or SSBTKA, to better understand the risk associated with SSBTKA brought about by increased age and associated comorbidities. Based on the results of the current study, no significant difference was found in postoperative complications between age groups or procedure. However, in line with previous literature [7, 9–14], there potentially

Table 3 Reasons for postoperative emergency room visits and readmissions within 90-days

	Procedure	Age	Primary reason
Emergency Room Visits	Unilateral	54	Headaches
	Unilateral	61	Pain—Negative for Deep Vein Thrombosis
	Unilateral	66	Transient Global Amnesia
	Unilateral	68	Constipation
	Unilateral	79	Knee Contusion from Fall
	Unilateral	84	Bilateral Foot Pain
	Unilateral	87	Shortness of Breath and Chest Pain
	Bilateral	74	Acute Back Pain & Shoulder Impingement
	Bilateral	74	Chronic Congestive Heart Failure
	Readmissions	Unilateral	62
Unilateral		68	Pancreatic Cancer
Unilateral		70	Acute Cholecystitis with Septic Shock
Unilateral		84	Shortness of Breath; COVID Positive
Bilateral		50	Weakness and Fever—Gout Related
Bilateral		59	Anemia
Bilateral		59	Bilateral Pulmonary Embolism
Bilateral		74	Upper Extremity Pain—Gout Related
Bilateral		77	Persistent Hypotension and Low Oxygen Saturation
Bilateral		80	Anemia and Mild Hypoxia
Bilateral	85	Traumatic Wound Dehiscence—No Infection	

Table 4 Charlson comorbidities by age groups and procedure—frequency (%)

	Unilateral			Bilateral			Uni vs Bilateral	
	≤ 70	> 70	<i>p</i> value	≤ 70	> 70	<i>p</i> value	≤ 70	> 70
Myocardial infarction	3 (4.0%)	8 (11.9%)	0.073	3 (6.3%)	2 (4.9%)	0.575	0.435	0.190
Congestive heart failure	3 (40.0%)	2 (3.0%)	0.553	0 (0.0%)	1 (2.4%)	0.461	0.223	0.679
Peripheral vascular disease	1 (1.3%)	1 (1.5%)	0.723	0 (0.0%)	1 (2.4%)	0.461	0.610	0.617
CVA or transient ischemic disease	5 (6.7%)	5 (7.5%)	0.554	0 (0.0%)	6 (14.6%)	0.008	0.080	0.192
Hemiplegia	–	–	–	–	–	–	–	–
Pulmonary Dx	4 (5.3%)	5 (7.5%)	0.429	0 (0.0%)	2 (4.9%)	0.209	0.134	0.462
Diabetes	8 (10.7%)	14 (20.9%)	0.074	11 (22.9)	4 (9.8%)	0.084	0.059	0.105
DM end-organ	1 (1.3%)	1 (1.5%)	0.723	0 (0.0%)	2 (4.9%)	0.209	0.610	0.321
Renal disease	5 (6.7%)	9 (13.4%)	0.143	1 (2.1%)	14 (34.1%)	<0.001	0.242	0.011
Mild chronic liver disease	2 (2.7%)	3 (4.5%)	0.447	–	–	–	0.370	0.235
Severe liver disease	0 (0.0%)	1 (1.5%)	0.472	–	–	–	–	0.620
Ulcers	5 (6.7%)	6 (9.0%)	0.421	4 (8.3%)	6 (14.6%)	0.273	0.494	0.272
Cancer	9 (12.0%)	15 (22.4%)	0.077	2 (4.2%)	8 (19.5%)	0.025	0.121	0.460
Metastatic solid tumor	–	–	–	0 (0.0%)	1 (1.1%)	0.461	–	0.380
Dementia	1 (1.3%)	1 (1.5%)	0.723	–	–	–	0.610	0.620
Rheumatic Dx	5 (6.7%)	10 (14.9%)	0.092	2 (4.2%)	1 (2.4%)	0.560	0.438	0.033
HIV or AIDS	0 (0.0%)	1 (1.5%)	0.472	–	–	–	–	0.620
Hypertension	44 (58.7%)	52 (77.6%)	0.012	35 (72.9%)	33 (80.0%)	0.279	0.078	0.460
Skin Ulcer	1 (1.3%)	1 (1.5%)	0.723	1 (2.1%)	2 (4.9%)	0.440	0.630	0.321
Depression	9 (12.0%)	7 (10.4%)	0.491	2 (4.2%)	2 (4.9%)	0.630	0.121	0.262
Anticoagulants	0 (0.0%)	1 (1.5%)	0.472	0 (0.0%)	1 (2.4%)	0.461	–	0.617

Significant *p* values are shown in bold for easier identification.

CVA cerebrovascular accident, Dx diagnosis, DM End-organ diabetes mellitus with end-organ damage, HIV human immunodeficiency virus, AIDS acquired immunodeficiency syndrome

was a slight increased rate of transfusions ($p=0.068$) and readmissions ($p=0.068$) for patients > 70 undergoing BTKA compared to unilateral TKA. Reasons for readmissions were implied to be unrelated to the arthroplasty per emergency physician and admitting hospitalist reports and indicated that these were more likely related to pre-existing conditions. However, except for the single patient readmitted for upper extremity pain, all other causes for readmission may be related to the index BTKA. The failure to demonstrate statistical significance may reflect small group sizes and surgeons should still be wary of the trend toward significance demonstrated. As expected, CCI and the total number of comorbidities were significantly greater for patients > 70, with SSBTKA patients having a higher rate of renal and transient ischemic heart disease. Interestingly, these conditions did not influence readmission rates, with only three patients with renal disease (one ≤ 70 and two > 70) and one patient with transient ischemic heart disease (≤ 70) being readmitted within 90 days post-arthroplasty.

Previous research has identified DVT and superficial infection as the most common postoperative complications occurring in elderly patients [26], with the incidence of DVT and PE increasing up to 80% following SSBTKA compared

to unilateral TKA (UTKA) [9, 11–14]. While no wound infections were reported in the current study, one DVT was reported in a unilateral patient ≤ 70. This low incidence was also present for SSBTKA, with one DVT occurring in each age group and two PEs occurring in bilateral patients ≤ 70. The low incidence of systemic complications and the relatively small number of patients in each subgroup limited the ability to find statistical significance. Despite the small numbers, this study demonstrated that SSBTKA in elderly patients can result in low overall complications. While the risk of systemic and wound complications is likely multifactorial, the low incidence of complications could be influenced by surgical experience, efficiency and overall multidisciplinary coordination of perioperative care combined with rapid therapy protocols which encourage ambulation on the day of surgery and twice daily during hospitalization. Greater experience and efficiency, as measured by shorter tourniquet and surgical times, have previously been postulated to decrease the risk of these complications [27–29]. Tourniquet times previously reported at the current study site are low, averaging 37 min per knee and SSBTKA total surgical time, to include transition time between knees, averaging about 155 minutes [30, 31].

Table 5 Clinical and patient reported outcomes for unilateral and bilateral patients between age groups—mean (SD)/freq (%)

	Unilateral			Bilateral			Uni vs Bilateral	
	≤70	>70	<i>p</i> value	≤70	>70	<i>p</i> value	≤70	>70
Number of patients	75	67		48	41			
Pre-operative								
KSS knee*	44.5 (16.7)	42.1 (17.8)	0.448	40.3 (13.3)	40.5 (13.1)	0.941	0.181	0.626
KSS function	61.9 (19.1)	48.5 (20.3)	<0.001	50.0 (17.5)	53.7 (17.6)	0.349	0.002	0.187
KOOS Jr*	45.2 (13.9)	46.5 (14.5)	0.588	46.7 (15.3)	44.9 (12.8)	0.556	0.585	0.559
G. Physical Health	40.3 (7.1)	40.4 (6.8)	0.907	38.6 (6.2)	39.8 (4.8)	0.344	0.189	0.588
G. Mental Health	48.7 (9.1)	48.8 (7.9)	0.920	46.0 (7.8)	49.9 (8.3)	0.029	0.098	0.522
Post-operative								
KSS Knee*	81.3 (12.5)	78.4 (13.2)	0.193	79.4 (15.7)	85.7 (9.7)	0.027	0.450	0.003
KSS function	52.4 (19.2)	43.8 (20.2)	0.011	55.4 (19.5)	49.8 (20.5)	0.185	0.401	0.143
KOOS Jr*	59.1 (9.7)	59.1 (11.7)	0.986	58.2 (11.1)	63.5 (12.7)	0.039	0.646	0.067
G. Physical Health	42.8 (6.1)	43.5 (5.8)	0.528	44.2 (6.2)	44.9 (6.9)	0.582	0.248	0.243
G. Mental Health	49.4 (8.9)	49.4 (8.7)	0.986	49.2 (8.5)	51.2 (7.8)	0.257	0.904	0.288
Pre-to-post change								
KSS Knee*	37.6 (16.7)	36.9 (24.7)	0.853	38.8 (22.7)	45.0 (16.9)	0.175	0.764	0.078
KSS function	-8.8 (23.9)	-4.4 (26.1)	0.325	9.1 (22.1)	-4.5 (18.3)	0.004	<0.001	0.978
KOOS Jr*	14.0 (15.4)	12.9 (14.9)	0.682	10.7 (16.4)	19.1 (16.9)	0.023	0.272	0.056
G. Physical Health	2.5 (6.8)	3.0 (5.6)	0.696	5.5 (6.7)	5.2 (6.8)	0.793	0.020	0.072
G. Mental Health	0.7 (8.1)	0.7 (7.4)	0.996	3.4 (7.2)	1.6 (6.3)	0.218	0.064	0.524
Satisfaction			0.317			0.048	0.923	0.018
Not answered	5	4		3	1			
5	39 (55.7%)	41 (65.1%)		27 (60.0%)	30 (75.0%)			
4	18 (25.7%)	9 (14.3%)		10 (22.2%)	10 (25.0%)			
3	7 (10.0%)	10 (15.9%)		5 (11.1%)	0 (0.0%)			
2	5 (7.1%)	3 (4.8%)		3 (6.7%)	0 (0.0%)			
1	1 (1.4%)	0 (0.0%)		0 (0.0%)	0 (0.0%)			

Significant *p* values are shown in bold for easier identification

SD standard deviation, *Freq* frequency, *KSS* knee society score, ° = degree, *KOOS JR* knee injury and osteoarthritis outcome score, joint replacement, *G* global

* = determined for each knee, doubled sample size

The transfusion rate experienced by this cohort was also relatively low. Previous research has reported approximately 20% of patients undergoing SSBTKA with use of intravenous tranexamic acid require postoperative transfusion [32, 33], which is significantly greater than the 5.6% (5/89) of SSBTKA patients in the current study requiring transfusion, regardless of age. Of the five patients requiring a transfusion, four of those patients were >70 years old. It is well established that the prevalence of anemia increases with age [34], which is supported in the current study as a significantly greater percentage of patients >70 qualified as anemic compared to patients ≤70 prior to surgery. Based on this finding, preoperative anemia screening may be helpful, especially in older patients, to identify patients at risk for postoperative transfusion.

Previous research has found that patients with knee osteoarthritis may present with greater comorbidities due

to low functional capacity brought about by knee pain and dysfunction [35, 36]. As expected, the average preoperative KSS-F score was significantly lower for patients ≤70 requiring SSBTKA than for patients with unilateral disease, however, this was not significant for patients >70. This suggests that patients with symptomatic bilateral knee arthritis have greater functional loss at younger ages and as patients age, unilateral knee pain has greater functional impact. Interestingly, SSBTKA patients ≤70 had a significantly greater improvement in KSS-F scores at six weeks than all three other groups and was the only group to demonstrate functional improvement compared to preoperative scores. This suggests that surgical intervention may be more beneficial when performed earlier, particularly for those with bilateral disease. Previous studies generally report lower ages for SSBTKA patients compared to unilateral patients, with the average age of SSBTKA patients ranging between 62 and

66 years old [16, 37]. The increased functional impact of bilateral knee pain may account for patients seeking earlier treatment, as well as surgeon selection bias towards reserving SSBTKA for younger patients. By evaluating SSBTKA in two specific age groups (average 63.9 and 75.8), the current study attempted to identify a difference in the distribution of comorbidities as it relates to age. In this cohort, only cerebrovascular accident, renal disease and cancer were found to be significantly more common in the older age group. A potential confounding variable, however, could be the distribution of race between the current study and previous research. Most studies regarding SSBTKA have involved predominantly Caucasian patients (range 61–82%) [16, 37]. In the current study, 38.7–61.0% of patients in each group self-identified as Asian. While it is unclear how this may influence the results, the demographic differences between this study cohort and large national studies are substantial and worthy of discussion.

In a recently published review of the National Surgical Quality Improvement Program (NSQIP) data base, BTKA was found to have increased risk for all complications and major complications when compared to UTKA regardless of health status [37]. While it is extremely difficult to compare such large database driven research with much smaller single center cohort evaluations, the conflicting findings in the current study require scrutiny and discussion of possible causes for these differences. One potential explanation is the notable differences between the current study's patient cohort and what appears to represent more national demographics of the US. Asian patients represented a substantial proportion of patients in the current cohort (38.7–61.0%) compared to 1.0–3.7% represented in the NSQIP data. Furthermore, there was a far greater proportion of Native Hawaiian or Pacific Islanders (NHPI) included (7.3–12.0%) compared to NSQIP statistics (0.2–0.7%). Half to 71% of patients in the current study had an ASA > 2 compared to nearly 82% of BTKA patients in the highest morbidity quartile of the NSQIP patient cohort. The average BMI of the current study group (28.6–30.8) was notably lower than the average BMI of all patients (31.3–37.4) except in the lowest NSQIP morbidity quartile. The proportion of BTKA patients in the current study (31.7–43.3%) being treated for diabetes appeared to be greater than the proportion of diabetic BTKA patients in the worse morbidity quartile of Warren et al.'s study (29.8%) and far greater than all other quartiles reviewed (4.1–16.6%) [37]. The multiple demographic differences between cohorts make direct comparisons difficult. It is possible that despite having more diabetic patients in the current study, overall, the BTKA patients in the current study represent a healthier group compared to the continental US and highlights the possibility that diabetes may not have the same health implications for Asian and NHPI. Furthermore, there is likely wide variability across the surgical

protocols used to perform BTKA and institutional experience and efficiency of hospitals contributing data to NSQIP. For all these reasons, direct comparisons to other studies are difficult to perform and highlights the importance of continuing site-specific evaluations to potentially identify local or demographic specific factors conducive to failure or success. The current study site is arguably the most geographically isolated, high-density population in the US which facilitates the study of geographically specific population demographics. Research is ongoing at the current study site to examine the impact of racial differences in outcomes following TKA particularly for Asian and NHPI patients.

In addition to low complication rates, the average, 6-weeks postoperative KOOS JR scores increased beyond the minimum clinically important difference values in all groups [38]. This improvement was greatest in bilateral patients > 70, which indicates that older patients may have different expectations following surgery, with a primary desire for the removal of pain as opposed to greater functional improvements. While improvement in SSBTKA patients > 70 was significantly greater than in patients ≤ 70, the difference in improvement for SSBTKA patients > 70 was not significantly different when compared to unilateral TKA patients > 70. This aligns with similar studies of elderly TKA patients which report no significant differences in postoperative function between unilateral and bilateral TKA [9, 39–41]. Clinical improvement in the current study for SSBTKA patients > 70 is further supported by the high level of patient satisfaction at six weeks following surgery; satisfaction scores were significantly greater than those of bilateral patients ≤ 70 and unilateral patients > 70. Coupled with the low complication rate, the high satisfaction following SSBTKA appears to support this surgical option for patients > 70.

The current study has several limitations. First, as previously mentioned, this was a single center and single surgeon cohort and may lack generalizability. However, the current study's design potentially decreases confounding variables compared to studies that use multiple surgeons and/or centers. Second, the unique patient demographic evaluated in the current study (38.7–61.0% Asian) may have contributed to differences between the current study and previous research. Further evaluation of comorbidity distribution as it relates to ethnicity is ongoing at the current study site. Third, the short follow-up time limits the ability to draw long-term conclusions about functional recovery and mortality. However, the 90-days complication reporting time is commonly used in research to evaluate wound and systemic complications. The short functional recovery evaluation was used as a secondary outcome to provide a broader scope of patient recovery, however, the short follow-up unlikely provides useful long-term insight. Fourth, it is highly possible that a selection bias occurs naturally in patient self-selection of SSBTKA.

Patients > 70 undergoing SSBTKA had significantly higher preoperative mental health self-assessment scores. There is a high possibility that patients who are more confident and have a healthier outlook of themselves have fewer concerns undergoing SSBTKA and can cope with postoperative stressors in a healthier manner. Postoperatively this group reported higher KSS-K and KOOS Jr. scores and 100% reported being satisfied or very satisfied following surgery compared to the younger SSBTKA group or both unilateral TKA groups. This may reflect the underlying characteristics of older patients choosing SSBTKA rather than surgery having improved outcomes in this age group. Finally, the small sample size and low occurrence of complications and readmissions limited the ability to find statistical differences. Larger randomized controlled trials of single center cohorts evaluating the safety of SSBTKA should be performed in the future to gain higher levels of evidence. However, single center cohorts of SSBTKA are commonly small and the authors hope these results add to the growing breadth of research on the topic.

Conclusion

The current study suggests there are no significant differences in early postoperative complications between patients younger and older than 70, or between unilateral and SSBTKA. However, a higher readmission rate trended toward significance in this relatively small cohort of SSBTKA patients > 70, and surgeons should continue to be cautious until greater evidence confirming safety can be demonstrated. The current study, however, resulted in low overall complication rates following SSBTKA in elderly patients with significant improvements in KOOS JR scores and high levels of patient satisfaction. These findings suggest SSBTKA should remain a reasonable option for patients older than 70.

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Data availability All data relevant to this study is secured in a data repository and can be accessed through the study institution for scientifically reasonable inquiries.

Declarations

Conflict of interest All authors certify that they have no affiliations with or involvement in any organization or entity with any financial

interest or non-financial interest in the subject matter or materials discussed in this manuscript.

Ethical approval This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Hawai'i Pacific Health Research Institute (local Western Institutional Review Board) approved this study.

Informed consent This was a retrospective chart review and data collected were de-identified and presented as large scale, aggregate data. Therefore, no informed consent was obtained or required by the IRB.

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