Trends in Bilateral Total Knee Arthroplasties

153,259 Discharges between 1990 and 2004

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Abstract Information regarding national trends in bilateral TKAs is needed for a rational allocation of resources, policy making, and research. Therefore, we analyzed data from the National Hospital Discharge Survey to elucidate temporal changes in the demographics, comorbidity profiles, hospital stay, and in-hospital complications of patients undergoing bilateral TKAs in the United States. We created three 5-year periods: 1990–1994, 1995–1999, 2000–2004. Procedure, healthcare system, and patient-related variables were analyzed for an estimated 153,259 discharges. Use of bilateral TKAs more than doubled for the entire civilian population and almost tripled among the female population, with the steepest increase seen during the last two study periods. A decline of nearly 50% in the use of bilateral TKAs in patients 85 years and older was

seen between the second and third study periods. The prevalence of coronary artery disease and pulmonary disease increased from the first to the second study periods but decreased from the second to the third. The changes in the variables studied may reflect a recently acquired reluctance to perform bilateral TKAs in elderly patients with cardiopulmonary comorbidities. Additional studies are necessary to identify other causal relationships and define the impact of these changes on various aspects of the healthcare system.

Level of Evidence: Level II, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

The use of TKAs for treatment of end-stage osteoarthritis has steadily increased during the last decades [15, 19]. Refinements in anesthetic and surgical techniques and perioperative care of patients undergoing TKA have allowed the performance of bilateral single-stage TKAs (BTKA). Despite potential advantages of the simultaneous approach regarding overall cost, recovery time, and patient convenience [13, 15, 27], the safety of simultaneously performed procedures has been questioned in the face of higher morbidity (49%) and mortality (66%) when compared with unilateral TKAs [20, 26].

Recently, we have used the information on knee arthroplasties collected for the National Hospital Discharge Survey (NHDS) in two studies [19, 20]. The first study was a pilot analysis of the trends in the use of primary and revision TKAs in the United States. That study described the trends in patient demographics, comorbidities, hospital stay, complications, and mortality with TKA [19] and

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showed a substantial increase in the use of TKAs in the United States between 1990 and 2004. In the second study, the NHDS was used to ascertain whether complications and mortality were greater in patients undergoing BTKAs as compared with those undergoing unilateral TKA and revision TKAs. We detected an increased incidence of complications and mortality [20]. We did not analyze temporal trends regarding usage, and it is uncertain if there have been any changes in the use of BTKAs in the United States. BTKAs represent less than 4% of all TKAs performed in the United States [25]. Consequently, institutional data from primarily large-volume hospitals will not be able to detect changes in the national trends in the use of BTKAs.

The national trends for use of BTKAs are not only informative but also can be used to project use of the procedure in the future and may allow a rational allocation of resources for the care of patients having the procedures. In addition, it may give the orthopaedic community baseline information for future studies seeking to determine the patient and hospital variables associated with the lowest perioperative risks.

Therefore, we addressed the following question: Are there any temporal changes in the use, demographics, comorbidities, in-hospital complications, hospital stay, discharge disposition, and hospital characteristics (including bed size and location) of patients undergoing BTKAs in the United States?

Materials and Methods

We obtained NHDS multiyear data files from the Centers for Disease Control and Prevention in Atlanta, GA. The plan and operation of the NHDS has been described [3]. The NHDS provides a nationally representative sample of data collected for in-hospital admissions from Medicare-participating, nonfederal, nongovernmental hospitals of various sizes throughout the 50 United States and the District of Columbia. Weights are provided in the data files that allow for calculation of unbiased national estimates from the sample. The use of the NHDS for study of TKAs has been described [19, 20].

Among the information collected in the survey are diagnosis and procedure codes (International Classification of Diseases, 9th Revision, Clinical Modification [ICD-9-CM] [9]), patient and hospital demographics, and information on length of stay, discharge disposition, geographic location, and source of payment. To ensure accurate, nationally representative sampling, the NHDS uses a complex three-stage probability design and uses multiple steps to ensure validity and accuracy of coding and data entry. The NHDS has been used extensively to analyze

temporal trends and results associated with a wide range of procedures across various medical specialties [31].

For our analysis, we obtained data collected for each year between 1990 and 2004 and imported them into a software program (SAS[®] Version 8.2; SAS Institute Inc, Cary, NC). We first identified discharges with a procedure code for primary TKA (81.54). Next, we identified discharges with this procedure code appearing twice as bilateral procedures and included them in the sample. To simplify analysis of temporal changes, three 5-year periods were created (1990–1994, 1995–1999, 2000–2004). We evaluated changes in the prevalence of procedures and trends in age, gender, race, length of stay, distribution of procedures by hospital size, US region, and disposition status across times. Frequencies of procedure-related complications with time were analyzed by determining cases that listed ICD-9-CM diagnosis codes specifying complications of surgical and medical care (996–999) [9]. In addition, we studied the prevalence of acute posthemorrhagic anemia and trends in comorbidity profiles by determining the prevalence of hypertension, diabetes mellitus, obesity, hypercholesterolemia, pulmonary disease, renal disease, and coronary artery disease. We included ICD-9-CM diagnosis codes to determine the presence of comorbidities and adverse diagnoses (Table 1) [9].

Intercensus population estimates determined by the US Census Bureau and provided by the Centers for Disease Control and Prevention in companion data files [21] were used to express age- and gender-adjusted prevalence of BTKA in each period as a rate per 100,000 of the US civilian population. We used the mean age- and gender-adjusted population estimates for a given 5-year study period as a denominator. A similar methodology has been used previously [14, 15].

We assessed differences in the prevalence between times for category groups (age group, gender category, race category, distribution of procedures by hospital size, US region, and disposition status) using a chi square test. Z-scores were calculated to determine differences in the proportions between times for specific variables in these categories. Differences for the continuous variables of age and length of stay between times were analyzed using a general linear model.

Results

The absolute number and use of BTKAs increased in the three periods of the study. Of an estimated total of 153,259 discharges after BTKAs (Table 2), 20.18% were performed between 1990 and 1994, 28.73% between 1995 and 1999, and 51.08% between 2000 and 2004. Use of BTKAs more than doubled for the entire civilian population and almost

Table 1. ICD-9-CM diagnosis codes used in study*

Diagnosis	Diagnosis code
Comorbidities	
Hypertension	401, 402, 403, 404, 405
Diabetes mellitus	250
Hypercholesteremia	2720
Obesity	278
Pulmonary disease	490, 491, 492, 493, 494, 496
Renal disease	582, 585, 403
Coronary artery disease	412, 413, 414, 4292
Procedure-related complications	
Device-related complications	996
Central nervous system	9970
Cardiac	9971
Peripheral vascular	9972
Respiratory	9973
Gastrointestinal	9974
Genitourinary	9975
Other organ-specific	9976–9979
Postoperative shock	9980
Hematoma/seroma	9981
Accidental puncture/laceration	9982
Disruption operative wound	9983
Postoperative infection	9985
Other complications of procedure	9986–9989
Complications of medical care	999
Other adverse events	
Acute posthemorrhagic anemia	2851

* Four- and five-digit codes are included under the respective three- and four-digit codes; ICD-9-CM = International Classification of Diseases, 9th Revision, Clinical Modification [9].

tripled among the female population (Fig. 1), with the steepest increase seen during the last two periods studied. However, the percentages of BTKAs as a function of the total number of TKAs remained relatively stable throughout the three study periods (3.83%, 3.66%, and 4.31%, respectively).

Among the demographic variables studied, the proportion of male patients and the age at the time of BTKAs decreased. The proportion of female patients undergoing BTKA increased from 54.62% in the first period (1990–1994) to 62.56% in the last period (2000–2004) (Fig. 2). Between 1990 and 1994, the use of BTKA/100,000 inhabitants/5-year period was similar between men and women (11/100,000/5-year period and 13/100,000/5-year period, respectively). Between 2000 and 2004, the use of BTKAs increased for men and women (21/100,000/5-year period and 33/100,000/5-year period, respectively). All age groups experienced an increase in the use of BTKAs throughout the study period, except the group 85 years and

Table 2. Characteristics of patients discharged after BTKAs (1990–2004)

Variable	Value
Total number	153,259
Average age (years)*	66.61 (20–930)
Average length of care (days)*	5.80 (1–53)
Age groups	
< 45 years	1.21%
45–64 years	39.00%
65–84 years	57.61%
> 85 years	2.19%
Gender	
Male	41.16%
Female	58.84%
Race	
White	61.14%
Black	3.62%
Other	1.64%
Not stated	33.60%
Discharge status	
Routine discharge to primary residence	29.02%
Discharge to short-term care facility	3.16%
Discharge to long-term care facility	37.16%
Alive, disposition not stated	24.00%
Dead	0.47%
Not stated or reported	6.18%
Hospital size (bed number)	
6–99	18.37%
100–199	21.21%
200–299	26.02%
300–499	25.30%
500+	9.11%
US region	
Northeastern	25.45%
Midwestern	49.65%
Southern	17.69%
Western	7.20%
Primary source of payment	
Medicare	49.41%
Medicaid	1.25%
Private	34.31%
Other†	14.63%
Not stated	0.39%

* Values expressed as averages, with ranges in parentheses; †includes sources listed in the National Hospital Discharge Survey as Workmen's Comp, Title V, Other Government, No Charge, Other.

older (Fig. 3). Between the second and third periods of study, a decline of nearly 50% was seen. The distribution of BTKAs among age groups changed substantially, with an increased proportion of patients between the ages of

Fig. 1 The figure shows the temporal changes in gender-adjusted and unadjusted use of BTKAs by time. The use of BTKAs more than doubled for the entire population and almost tripled among the female population, with the steepest increase seen during the last two times. The values are expressed as number per 100,000 US civilians per time.

Fig. 2 The figure shows the gender distribution of BTKAs with time. The proportion of female patients undergoing BTKAs increased ($p < 0.001$) from 54.62% in 1990–1994 to 62.56% in 2000–2004.

45 and 64 years receiving BTKAs (32.83% in 1990–1994; 43.62% in 2000–2004) (Fig. 4). This trend of BTKAs being performed in younger patients was paralleled by a substantial decrease in mean age of 2.5 years during the last decade (67.62 years in 1990–1994, 67.95 years in 1995–1999, 65.44 years in 2000–2004).

Fig. 3 The figure shows the changes in age group-adjusted and unadjusted use of BTKAs by time. All age groups experienced an increase in use of BTKAs throughout the study period, except the group 85 years and older. Between the second and third periods of study, a decline of nearly 50% was seen. The values are expressed as number per 100,000 US civilians per time.

Fig. 4 The figure shows the age group distribution of BTKAs with time. There was an increased ($p < 0.001$) proportion of patients between the ages of 45 and 64 years receiving BTKAs (32.83% in 1990–1994; 43.62% in 2000–2004). For every age group, a difference was found between times ($p < 0.001$), except for < 45 years group between 1990–1994 and 1995–1999 ($p = 0.2546$).

Fig. 5 The figure shows the prevalence of comorbidities among patients undergoing BTKAs with time. Error bars represent standard errors. There was an increase ($p < 0.001$) in the prevalence of diabetes mellitus, hypercholesterolemia, obesity, and renal disease with time. The prevalence of coronary artery disease and pulmonary disease increased ($p < 0.001$) from the first to the second periods but decreased ($p < 0.001$) from the second to the third periods of study. Hypertension data are not shown in the graph.

Comorbidity burden increased with time for hypertension, diabetes mellitus, hypercholesterolemia, obesity, and renal disease. Hypertension was the most prevalent comorbidity in every period, affecting 28.9%, 38.36%, and 50.37% of patients, respectively ($p < 0.001$ between all times). The prevalence of coronary artery disease and pulmonary disease increased from the first to the second periods but decreased from the second to the third periods of study (Fig. 5).

Overall, procedure-related complications captured during hospitalization decreased with time from 19.85% in the first period to 8.89% in the most recent period studied (Figs. 6, 7). Although a decrease was seen for all organ-specific complications with time, complications affecting the pulmonary system remained relatively unchanged during the last decade of the study, making respiratory and cardiac the most commonly encountered complication in 2000 to 2004.

The length of hospital stay decreased from 9.27 days (range, 2–53 days) between 1990 and 1994 to 5.44 days (range, 1–44 days) between 1995 and 1999 and to 4.68 days (range, 1–33 days) between 2000 and 2004.

Although the most common discharge disposition was to the patient's customary residence between 1990 and 1994 (50.17%) and only approximately $\frac{1}{4}$ of patients were discharged to a long-term care facility (26.12%), only 23.34% of patients after BTKAs were released to their customary residence and 36.28% went to a long-term care facility in

Fig. 6 There was a decrease ($p < 0.001$) in the procedure-related complications (ICD-9-CM 996–999) captured during hospitalization following BTKAs with time. Error bars represent standard errors.

Fig. 7 There was a decrease in organ-specific procedure-related complications associated with BTKAs with time ($p < 0.001$ between all periods for all organ systems, except pulmonary complications between 1995–1999 and 2000–2004 [$p = 0.0019$] and cardiac complications between 1990–1994 and 1995–1999 [$p = 0.3085$]). Error bars represent standard errors.

the most recent period studied. However, the number of patients for whom disposition documentation is incomplete doubled from 18.06% to 37.52%, thus clearly limiting the interpretation of these findings.

Fig. 8 The figure shows distribution of BTKAs by hospital size (number of beds) with time. There was an increasing number of BTKAs being performed in smaller hospitals ($p < 0.001$ between all periods for all bed size groups, except the 500 + category between 1990–1994 and 1995–1999 [$p = 0.0099$]).

Among the hospital characteristics studied, we detected a shift toward BTKAs being performed in smaller hospitals and an increasing number of BTKAs being performed in the southern and western regions of the country. Although between 1990 and 1994 only approximately 15% of BTKAs were performed in hospitals with fewer than 200 beds, this proportion increased to 50% between 2000 and 2004 (Fig. 8). The majority of BTKAs were performed in the Northeastern and Midwestern regions of the United States; however, an increasing proportion was noted in the southern and western regions more recently (Fig. 9).

Discussion

In light of the possible increased risk for medical complications in patients undergoing BTKAs, it is uncertain if there have been any recent changes in the use of BTKAs in the United States. The United States national trends for use of BTKAs are not only informative but also can be used to project use of the procedure in the future and to provide a rational allocation of resources for the care of patients having the procedure. In addition, the trends may provide basic information for future studies seeking to delineate the patient and hospital variables associated with the lowest perioperative risks. Therefore, we studied the temporal changes in the use, demographics, comorbidities, in-hospital complications, hospital stay, discharge disposition, and hospital characteristics (including bed size and

Fig. 9 The figure shows distribution of BTKAs by US region with time. The majority of BTKAs were performed in the Northeastern and Midwestern regions of the United States; however, an increasing proportion was noted in the southern and western regions most recently. The differences between US region groups across periods of interest were significant ($p < 0.001$ between all times for all US region groups, except the Southwestern region category between 1990–1994 and 1995–1999 [$p = 0.1335$]).

location) of patients undergoing BTKAs in the United States.

Our study is limited by numerous factors inherent to secondary data analysis of large administrative databases. Clinical information available in the NHDS is limited and only inpatient data are available for analysis. Thus, complications and events after discharge from the hospital are not captured. Conclusions therefore should be limited to the acute postoperative setting, with the notion that complication rates are likely underestimated. We decided not to report on trends in mortality and other low-incidence events, because this was beyond the scope of this study, and it has been suggested estimates based on a very low sample size may be unstable [5]. The study is retrospective. Although patients undergoing BTKAs in our study were identified by the occurrence of the code for TKA twice, it is not possible to distinguish patients who had BTKAs performed during the same anesthetic session from those who underwent surgery at different times during their hospitalization. Others have reported this problem when analyzing data from Medicare enrollees [1]. Thus, national data on trends taking actual timing of BTKAs into account are not available. Despite rigorous quality assurance measures applied in the operation of the NHDS, it is likely diagnoses, particularly of chronic conditions, are under-coded [8]. Therefore, the incidence of comorbid diseases is likely higher than that reported in our study. In addition,

coding practices may have changed during the span of the study. Despite the previously mentioned limitations, the plan and operation of the NHDS have not changed during our study period, thus allowing for comparative trend analysis. Temporal analysis using NHDS data has been widely used in various medical fields and is accepted as accurate [17, 22, 31]. With a low incidence of BTKAs, the use of these data provides a rare opportunity to study trends associated with BTKAs that otherwise would not be available.

We observed substantial changes in most of the variables analyzed. Although in general use increased with time, operations decreased during the last decade on patients 85 years and older and among those with cardiac and pulmonary diseases.

Increase in the use of TKA during the last decades has been well described [14, 19, 20], but no such data are available for BTKAs. We found a 153% increase in the total number of BTKAs performed paralleled by a 127% increase in use during the time span of the study. In an analysis in which we studied the national trends in use of TKA in the United States covering the same time, we determined the rates and use for TKAs in general increased by 125% and 102%, respectively, thus suggesting the prevalence and population-adjusted use of BTKAs have increased at a faster pace [19].

The average age of patients undergoing BTKAs decreased by more than 2 years during the 15 years of our study accompanied by an increase in the proportion of patients 45 to 64 years and a decrease in patients 65 years and older. This trend toward younger patients having BTKAs also exists for unilateral TKAs [19] and may reflect the trend that surgeons are recommending earlier procedures and patients want the procedures earlier to avoid longer periods of preoperative pain and disability. Furthermore, although the age-adjusted use of BTKAs for each age group younger than 85 years increased, that for the population older than 85 years decreased. Similar trends among the general population receiving TKAs have been reported in studies of the United States and European populations [10, 18, 19, 30]. Although the reasons for this trend are multifactorial, the decrease in the proportion of the elderly undergoing TKAs is likely linked to evidence that increasing age is an independent risk factor for adverse outcomes after TKA, including BTKAs [2, 24, 28, 32]. It is reasonable to believe physicians seeking to minimize the risk of adverse outcome after BTKAs are likely to have adjusted their practice during the last decade to implement stricter risk stratification of patients.

We detected an increasing gender gap and increased use and overall proportion of BTKAs performed among women. Similar findings have been made in the general TKA population [14]. In our study, we detected a greater

increase in the use of BTKAs for women than for men. In the first period of the study (1990–1994), the use was 11/100,000/5-year period for men and 13/100,000/5-year period for women (16% greater use for women). In the last period of the study, the use for women (33/100,000/5-year period) was 33% higher than for men (21/100,000/5-year period). Kurtz et al. [14] described the national use of TKAs as 56/100,000/year for women and 40/100,000/year for men in 1990 (29% higher use for women). In 2002, the use increased to 80/100,000/year for women and 60/100,000/year for men (25% higher use for women) [14]. The disproportion of use of BTKAs among women detected during the last period of our study was higher than that reported by Kurtz et al. [14] for 2002 (60/100,000/year for men versus 80/100,000/year for women—a 25% difference) [14]. The discrepancies may be explained by the fact that osteoarthritis is more prevalent and more incapacitating in women than in men [6]. However, although gender is less likely an intentional factor for risk stratification in orthopaedic practice, the trends observed may be viewed positively, because male gender was associated with a higher risk of procedure-related complications, including pulmonary and cardiac, and has been linked to increased risk for mortality after simultaneous BTKAs and TKAs in general [24, 28, 29].

Patients with osteoarthritis reportedly have higher rates of comorbid disease than their peers when adjusting for age, gender, and socioeconomic factors [11]. We also found a high proportion of patients with various comorbidities [16]. Temporally, we identified an increase in the prevalence of comorbidities associated with metabolic syndrome, including hypertension, diabetes mellitus, hypercholesterolemia, and obesity, which reflects the trend in the general population as reported by the National Center for Health Statistics [7]. However, a decrease in the prevalence of cardiac and pulmonary diseases has been reported among patients undergoing BTKAs. Because increased comorbid disease, such as preexisting cardiopulmonary disease, has been associated with worse outcome after TKA [24], the observed trend may reflect the adaptation of more careful patient selection for this arguably more morbid procedure [24, 26].

The average length of hospital stay decreased by 50% from 9.17 days to 4.68 days during the time of the study. The largest decrease occurred from the first to the second study periods, 9.17 days to 5.43 days. This trend should be interpreted with caution in view of the absence of complete information on a temporally increasing proportion of discharge dispositions in the NHDS. Although the exact numbers may be unknown, the general trends of decreasing length of hospital stay and increasing rates of discharges to rehabilitation centers and other skilled nursing facilities in view of prospective pay and managed care introduced in

the 1990s has been described [4]. Although the trend may represent the desire for cost containment in an increasingly business-conscious environment, this trend most certainly leads to a shift of monitoring for potential complications to a setting that may be less well equipped to handle these events. Perhaps mildly reassuring are data suggesting 90% of major complications after lower extremity arthroplasty occur within 4.5 days postoperatively [23]. The average length of stay after BTKAs decreased during the study period (1990–2004) and additional study is needed to evaluate the safety of such early discharge and address the potentially increased rates of readmissions.

Overall, procedure-related complication rates decreased by approximately 50% during our study period. The decrease in length of stay from the first to the second study periods undoubtedly led to a reduction of the time window in which adverse events can be captured, thus introducing considerable bias. However, better patient selection and perioperative care may be partly responsible for a decrease in in-hospital procedure-related complications. In support of this is the fact that an additional decrease in procedure-related complications was seen between the second and third study periods during which there was only a mild reduction in the average hospital stay (5.44–4.68 days). Although it has been suggested the majority of major complications occur relatively early after lower extremity surgery [23] and it is likely improved surgical and anesthetic techniques have positively influenced outcomes after BTKAs, our data should be interpreted in the context of this limitation.

We found an increase in the proportion of BTKAs being performed at hospitals with fewer than 200 beds. This trend may reflect an increasing comfort level of surgeons with the procedure leading them to perform BTKAs at smaller facilities. This trend, however, should be viewed critically, because an association between higher hospital procedure volume and better outcomes after TKA has been described [12]. Despite the fact that procedure volume may not be linked directly to hospital size per se, as evidenced by the existence of specialized orthopaedic institutions with relatively low bed numbers, the relationship between outcomes and hospital size remains unstudied and requires additional evaluation. Presumably, larger hospitals may offer better access to ancillary services and may be better equipped to deal with nonorthopaedic complications.

Regional discrepancies in the use of BTKAs have been reported [11], but causal relationships remain poorly understood. However, in our trend analysis, we were able to show, despite persistence of regional discrepancies, the trend is toward reducing these disparities. The proportion of BTKAs performed in the southern and western regions of the United States has been increasing.

We identified numerous temporal changes associated with BTKAs performed during the same hospitalization. Despite limitations, we were able to identify an increase in the use of BTKAs. BTKAs in patients older than 85 years and among patients with pulmonary and coronary artery diseases decreased during the last decade. Overall procedure-related complication rates captured during hospitalization decreased by approximately 50% during the study period. Although causal relationships cannot be determined with our data, our analysis provides insights in the trends associated with BTKAs.

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