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Objectives

- To describe the different options for the surgical treatment of patients presenting with bilateral knee osteoarthritis.
- To describe the advantages of undergoing bilateral total knee arthroplasty under the same anaesthesia (single-stage).
- To describe the drawbacks and complications of single-stage bilateral total knee replacement surgery.
- To provide guidelines for the selection of candidates for single-stage bilateral total knee replacement surgery based on risk stratification.

- The drawbacks of single-stage bilateral total knee replacement surgery include increased risk of perioperative complications.
- Published guidelines for the selection of patients being considered for single-stage bilateral knee arthroplasty contemplate the exclusion of patients of extreme age—patients with significant end organ dysfunction (i.e. ASA physical status of 3 or greater).

Key Points

- Bilateral total knee replacements can be performed under the same anaesthetic or so-called “single-stage” (simultaneously or sequentially), or under different anaesthetics or so-called “staged” (during the same or different hospitalizations).
- The main advantages of single-stage bilateral total knee replacement surgery include good clinical results, the need for a single anaesthetic, lower total amount of pain medication used, shorter overall surgical and rehabilitation time, high patient satisfaction, and possibly lower total cost.

Introduction

Knee osteoarthritis affects approximately 80 % of the population above the age of 65 [1]. Thus, it is not surprising that the number of total knee arthroplasties (TKA) performed in the USA has been steadily increasing over the last decades [2–5].

Approximately 20 % of patients undergoing primary unilateral TKA complain of severe pain in the contralateral knee [6], and about 10 % of patients who have a primary TKA will undergo contralateral TKA surgery within 1 year [7].

Patients with debilitating bilateral joint disease represent a unique challenge. While proponents of performing single-stage bilateral total knee arthroplasties (BTKA) point out its low complication rates, high patient satisfaction, and cost-effectiveness [8–15] concerns persist that BTKA performed during the same anesthetic session is associated with increased morbidity and mortality [14–21]. Despite extensive research into risks and benefits of single-stage BTKA, many important questions related to the safety of the procedure remain unanswered [22–27]. Moreover, there are no scientifically based consensus guidelines to aid in appropriate patient selection.

In order to clarify terms to describe the chronologic relationship of the first and second joint arthroplasty in this chapter, the following definitions have been chosen:

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1. *Single-stage BTKA*: Both TKAs are performed during the same anesthetic session. Single-stage BTKA can be performed (a) *simultaneously*, when both TKAs are performed at the same time by different surgical teams or (b) *sequentially*, when TKAs are performed consecutively by the same surgical team.
2. *Staged BTKA*: Each TKA is performed in a separate anesthetic sessions. Staged procedures can be done *during the same hospitalization* (generally a few days apart) or *during different hospitalizations* separated by weeks to months.

The objective of single-stage BTKA surgery is to reduce the risk of repeated anesthetic procedures, total hospitalization and recovery time, and cost. The goal is to perform single-stage BTKA while maintaining patient safety, and the clinical and functional outcomes observed in patients undergoing unilateral TKA or staged BTKA [10, 11, 27–41]. In view of the divided opinions on the use of single-stage BTKA surgery, careful patient selection appears to be the safest clinical approach, as proponents point to good outcomes in selected patients at their institution [8, 16, 42–44]. In an attempt to reconcile competing factors in the decision making process to perform single-stage BTKA procedures, many institutions, including ours, have developed guidelines for the selection of patients considered to be at a low perioperative risk.

In this chapter we will discuss the published evidence in regard to multiple aspects surrounding BTKA procedures, including the epidemiology and trends, benefits and risks, and the approach taken at our institution as an example of how consensus can be reached to reconcile the benefits with concerns for patient safety.

Epidemiology and Trends

The performance of unilateral and bilateral TKA has increased dramatically over time [5, 24]. The proportion of BTKA to unilateral TKA in the USA was approximately 4 % between 1990 and 1994. The proportion rose to 6.5 % in the period between 1998 and 2006, indicating an increased popularity for this approach [45]. The absolute number and use of BTKAs also increased from 1990 to 2004. Of an estimated total of 153,259 discharges after BTKAs, 20.18 % were performed between 1990 and 1994, 28.73 % between 1995 and 1999, and 51.08 % between 2000 and 2004. From 1990 to 2004, the use of BTKAs more than doubled for the entire civilian population and almost tripled among the female population (Fig. 23.1), with the steepest increase seen between 1995 and 2004 [24].

Patients undergoing BTKA are on average younger and healthier compared with their counterparts undergoing

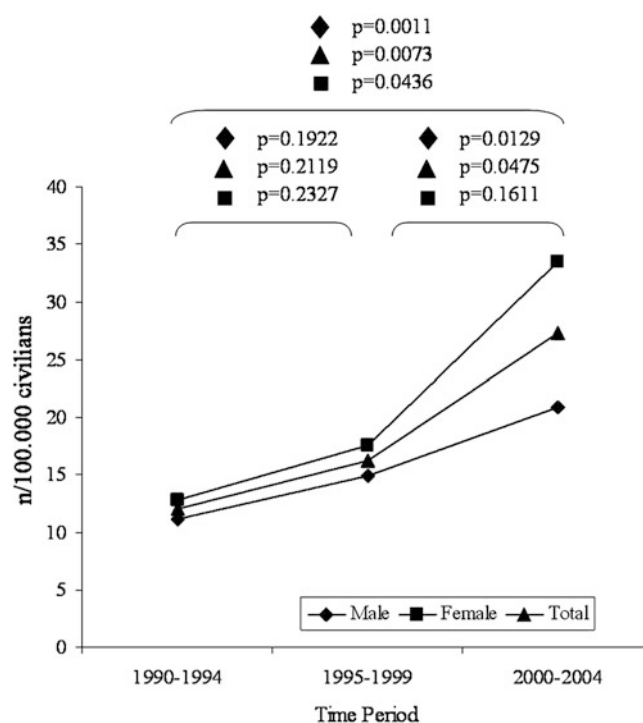


Fig. 23.1 Temporal changes in gender-adjusted and unadjusted use of BTKAs by time. The use of BTKAs more than doubled for the entire population and almost tripled among the female population, with the steepest increase seen during the last two study periods. The values are expressed as number per 100,000 US civilians per time (Used with permission from Memtsoudis SG, Besculides MC, Reid S, Gaber-Baylis LK, Gonzalez Della Valle A: Trends in bilateral total knee arthroplasties: 153,259 discharges between 1990 and 2004. Clin Orthop Relat Res 2009; 467:1568–76)

unilateral TKA [25, 45, 46]. Trends toward decreasing average age have paralleled those of unilateral TKA recipients [24]. However, while a shift toward increasing comorbidity burden was seen over time in the latter group, decreased rates of cardiac and pulmonary disease and utilization among the elderly (i.e. >85 years) have been noted in the BTKA group starting in the mid 1990s (Fig. 23.2). These trends may be explained by the desire of clinicians to perform BTKA, especially single-stage, in a healthier and younger group of patients, presumably in order to decrease the risk of perioperative complications.

Although male patients make up approximately 36 % of patients undergoing unilateral TKA, they are over proportionately represented in the BTKA group (41 %) [25].

These trends may be driven by the expansion of indications for TKA to younger, more active patients, the epidemic of obesity and its consequences in the progression of osteoarthritis [47], all factors resulting in a higher demand for the procedure. Advances in anaesthesia, surgery and perioperative care may further contribute to the increase in utilization of BTKA [24], as physician and patient confidence increase.

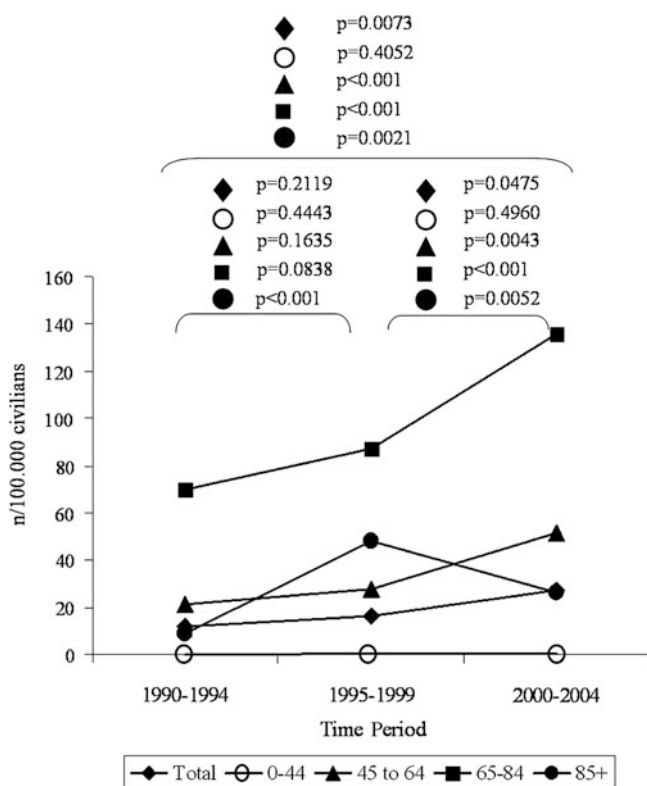


Fig. 23.2 Changes in age group-adjusted and unadjusted use of BTKAs by time. All age groups experienced an increase in use of BTKAs throughout the study period, except the group 85 years and older. Between the second and third periods of study, a decline of nearly 50 % was seen. The values are expressed as number per 100,000 US civilians per time (Used with permission from Memtsoudis SG, Besculides MC, Reid S, Gaber-Baylis LK, Gonzalez Della Valle A: Trends in bilateral total knee arthroplasties; 153,259 discharges between 1990 and 2004. Clin Orthop Relat Res 2009; 467:1568–76)

Benefits of Single-Stage Bilateral Total Knee Arthroplasty

The use of single-stage BTKA has advantages that include: good clinical results, the exposure to only one anesthetic, lower total amount of pain medication used, shorter overall surgical and rehabilitation time, high patient satisfaction, and possibly lower cost. See Table 23.1.

Clinical Results of Bilateral Total Knee Arthroplasty

Five studies [12, 14, 17, 48, 49] reporting on the clinical results of a combined number of 2,641 BTKA patients support that single-stage BTKA is a very successful operation, with results that are comparable to those of unilateral TKA. BTKA patients demonstrated similar or better results in terms of range of motion [17], Oxford Knee Score [17],

WOMAC [48], SF-36 [48], SF-12 [49], Knee Society Score [49], and survivorship at 7 years [14] and 10 years [12].

Number of Anesthetic Sessions

Although major anaesthesia related complications are rare, the risks associated with potential procedures, such as endotracheal intubation in the case of general anesthetic, neuraxial complications with a regional technique and those associated with the administration of drugs and insertions of invasive lines cannot be discounted completely. Thus, it is obvious that strictly from an anesthetic procedural aspect the avoidance of a second exposure may be of benefit.

Surgical Time

Predictably, surgical time varies with the type of BTKA performed. In 1998, Liu et al. compared operative time between 64 patients undergoing sequential BTKA, and 24 patients undergoing staged BTKA 7 days apart [50]. The mean operative and tourniquet time for patients undergoing sequential procedures was 19 min and 26 min shorter than for those undergoing staged BTKA, respectively. This is reflected not only in lower operating room costs but also in the reduction of potential risks associated with tourniquet application, such as nerve palsy, vascular injury, muscle damage, post-operative swelling and stiffness [51–57]. Other less frequent complications have also been reported with tourniquet use, such as intraoperative cardiac arrest at the time of deflation, reactive hyperaemia, early infection, and wound healing disorders due to perioperative hypoxia and reduced post-operative tissue perfusion [58–63].

Use of Pain Medication

The general belief is that patients undergoing single-stage BTKA will experience worse pain and will have a higher requirement for narcotics than those undergoing unilateral TKA. Three studies have challenged this belief: Powell et al. [64] observed that narcotic requirements were slightly greater but not significantly different for the simultaneous BTKA group compared with a unilateral TKA group during the first 72 h after surgery. They reported less pain in unilateral TKA recipients (mean 4.53 on a 0 (no pain) to 10 (maximum pain) visual analog scale (VAS)) than in BTKA patients (mean 5.83) in the early post-operative period. However, there was no statistically significant difference in pain scores after the first post-operative day. Surprisingly, patients who underwent simultaneous BTKA reported slightly less pain than those undergoing unilateral TKA after the first

Table 23.1 Studies reporting on series of consecutive BTKA patients

Author (year) [Type of study]	Number of patients	Modality (SA/DA)	Mean age (range)	Gender (M:F)	Follow- up	Life-threatening complications	Mortality
Alemparte et al. [8] (2002) [Re]	604	SA	70 (30–92)	35:65	1 year	3.1 %	0.7 %
Pavone et al. [42] (2004) [Re]	501	SA	66 (18–88)	43:57	N/A	10 %	0
Williams-Russo et al. [99] (1992) [Pr]	51	SA	68 (48–84)	45:55	7 days	2 %	0

Re retrospective, Pr prospective, SA single anesthetic, DA different anesthetic, N/A not available

post-operative day. Similarly, Shetty et al. [65], prospectively studied 50 patients undergoing sequential BTKA, and 50 undergoing unilateral TKA. The mean difference in post-operative VAS scores was significant only on the first post-operative day, becoming non-significant during the remainder of the hospitalization and at discharge. Moreover, Fick et al. [17], despite differences in the analgesic protocol, reported that opioid consumption was not statistically different between the BTKA and unilateral TKA groups.

Patient Satisfaction

Along with functional outcome, health status and perception of well-being are becoming increasingly important markers when evaluating TKA results [66]. In terms of functional results and implant survivorship, there is strong evidence suggesting that single-stage BTKA patients do as well as unilateral TKA recipients [10, 12–14, 18, 29, 31, 67, 68]. Furthermore, a large survival analysis conducted by Ritter et al. [10] on 2,050 simultaneous BTKA patients, 152 staged BTKA patients (performed within 1 year) and 1,796 unilateral TKA patients at 5, 10 and 15 years post-operatively concluded that patients who had undergone unilateral TKA had significantly lower Knee Society Scores compared with patients with simultaneous BTKA.

Patient satisfaction and health perception are also advantages of single-stage BTKA. It has been reported that the majority (94.7 %) of patients who had experienced BTKA would opt for the same procedure again [14]. Similar results were presented by other authors, reporting that patients undergoing simultaneous BTKA have improved physical and social function, less pain and better general and mental health than patients undergoing unilateral TKA [48].

Cost

If the combined cost of two unilateral TKAs exceeds the total cost of a single-stage BTKA, then the latter can be considered

to be more economical. Cost analysis performed by numerous authors [9, 28, 31, 35] showed that single-stage BTKA results in overall savings in the range of 18–58 % compared with the cost of staged procedures. The economical advantage of single-stage BTKA surgery is driven by numerous factors that include: a reduced hospital stay [30, 69], lower charges for laboratory tests, medical consultations, operating room fees, anesthesia and surgical fees, recovery room time, antibiotics, and physical therapy [14]. The cost in surgical fees for the insurance company are also lower as in the USA most insurers including Medicare reimburse the second joint replacement performed during the same anesthetic at 50 %.

When calculating the overall cost of care, both transfer to a rehabilitation centre and re-admission should be taken into consideration. One study [48] compared the 12-month clinical outcome of 198 unilateral TKA and 139 simultaneous BTKA patients. The proportion of patients being discharged to a rehabilitation centre was higher in the BTKA group (55 %) than in the unilateral TKA group (33 %). However, the proportion of patients readmitted within 12 months of surgery for condition related to the knee surgery was higher in the unilateral TKA group (12 %) than in the BTKA group (5 %). The majority of re-admission was due to limited range of motion requiring manipulation under anesthesia.

Drawbacks of Single-Stage Bilateral Total Knee Arthroplasty

Numerous studies report significantly higher complication rates for single-stage BTKA procedures [14–21] including increased mortality, cardiac complications, pulmonary complications, post-operative confusion, wound infection, use of allogenic blood transfusions, and discharge to tertiary rehabilitation centres (Table 23.2). The pathophysiology of bilateral procedures may be in part explained by the increased surgical insult, blood loss and embolic load affecting the various organ systems.

Table 23.2 Studies reporting on comparative unilateral TKA and BTKA surgery (*blank cells* indicate no significant difference observed)

Author (year) [Type of study]	Procedure type	Number of patients	Significantly higher local complications	Significantly higher systemic complications	Significantly higher mortality
Gradillas et al. [30] (1979) [Re]	UTKA	40	Yes (1a)		
	SSBTKA (sequential)	41		Yes (1b)	
Soudry et al. [39] (1985) [Re]	UTKA	156			
	SSBTKA (sequential)	56			
	SBTKA (1 wk to 5 mo)	18		Yes (2)	
Morrey et al. [11] (1987) [Re]	UTKA	501			
	SSBTKA (simultaneous)	145			
	SBTKA (one admission)	228			
	SBTKA (two admissions)	117			
Jankiewicz et al. [32] (1994) [Re]	SSBTKA (simultaneous)	99			
	SBTKA (9 mo)	56			
Worland et al. [84] (1996) [Re]	UTKA	107			
	SSBTKA (simultaneous)	213			
Lynch et al. [71] (1997) [Re]	UTKA	98			
	SSBTKA (simultaneous)	98		Yes (3)	
Cohen et al. [29] (1997) [Re]	UTKA	100			
	SSBTKA (simultaneous)	86			
Lane et al. [18] (1997) [Pr]	UTKA	100			
	SSBTKA (simultaneous)	100		Yes (4)	
Ritter et al. [70] (1997) [Re—DTB]	SSBTKA (simultaneous)	12,622		Yes (5b)	Yes
	SBTKA (6 wk)	4,354	Yes (5a)	Yes (5b)	
	SBTKA (3 mo)	4,524	Yes (5a)		
	SBTKA (6 mo)	9,829	Yes (5a)	Yes (5b)	
	SBTKA (1 yr)	31,401	Yes (5a)	Yes (5b)	
Liu and Chen [50] (1998) [Re]	SSBTKA (simultaneous)	64			
	SBTKA (1 wk)	24			
Adili et al. [67] (2001) [Re]*	UTKA	82			
	SSBTKA (sequential)	82		Yes (6)	
Lombardi et al. [15] (2001) [Re]	UTKA	958			
	SSBTKA (simultaneous)	1,090		Yes (7)	
Mangaleshkar et al. [100] (2001) [Re]	UTKA	367	NA	NA	
	SSBTKA (simultaneous)	54	NA	NA	Yes (8)
	SBTKA (>15days)	34	NA	NA	
Parvizi et al. [19] (2001) [Re]	UTKA	19,861	NA	NA	
	SSBTKA (simultaneous)	2,679	NA	NA	Yes
Fick et al. [17] (2002) [Pr]	UTKA	172			
	SSBTKA (simultaneous)	56			
Mantilla et al. [94] (2002) [Re]	UTKA	3,601			
	BTKA (various types)	1,410		Yes (9)	
Ritter et al. [10] (2003) [Re]	UTKA	1,796	Yes (10a)		
	SSBTKA (simultaneous)	2,050	Yes (10b)	Yes (10c)	
	SBTKA (<1–3 yrs)	152	NA	NA	NA
Bullock et al. [16] (2003) [Re]	UTKA	512			
	SSBTKA (simultaneous)	255		Yes (11)	
March et al. [48] (2004) [Pr]	UTKA	97			
	SSBTKA (simultaneous)	56		Yes (12)	
Stubbs et al. [49] (2005) [Re]	UTKA	125			
	SSBTKA (simultaneous)	61			
	SBTKA (1 yr)	38			
Sliva et al. [101] (2005) [Re]	UTKA	65	Yes (13)	Yes (13)	
	SSBTKA (sequential)	26			
	SBTKA (4.5 days)	241			

(continued)

Table 23.2 (continued)

Author (year) [Type of study]	Procedure type	Number of patients	Significantly higher local complications	Significantly higher systemic complications	Significantly higher mortality
Hutchinson et al. [102] (2006) [Pr]	UTKA	741			
	SSBTKA (simultaneous)	438	Yes (14a)	Yes (14b)	
	SBTKA (timing NA)	125	Yes (14a)	Yes (14b)	
Forster et al. [43] (2006) [Re]	SSBTKA (sequential)	28			
	SBTKA (1 wk)	36			
	SBTKA (29 mo)	38			
Urban et al. [72] (2006) [Re]	UTKA	293	NA		
	SSBTKA (sequential)	169	NA	Yes (15)	
Powell et al. [64] (2006) [Re]	UTKA	59			
	SSBTKA (simultaneous)	59			
Shah et al. [103] (2007) [Pr]	UTKA	174			
	SSBTKA (sequential)	87			
Stefansdottir et al. [104] (2008) [Re—DTB]	SSBTKA (simultaneous)	1,139	NA	NA	Yes
	SBTKA (<1 yr)	3,432	NA	NA	
Kim et al. [12] (2009) [Re]	UTKA	719			
	SSBTKA (sequential)	2,385			
Luscombe et al. [1] (2009) [Re]	UTKA	144			
	SSBTKA (simultaneous)	72	Yes (16a)	Yes (16b)	
Memtsoudis et al. [45] (2009) [Re—DTB]	UTKA	626,439			
	SSBTKA (17a)	25,179	Yes (17b, 17c)	Yes (17d, 17e)	Yes (17 g)
	SBTKA	8,483	Yes (17b)	Yes (17d, 17f)	Yes (17 g)
Yoon et al. [69] (2010) [Re]	SSBTKA (simultaneous)	119		Yes (18)	
	SBTKA (1 yr)	265			
Taylor et al. [44] (2010) [Re]**	UTKA	151			
	SSBTKA (simultaneous)	148			
Husted et al. [13] (2011) [Pr]	UTKA	271			
	SSBTKA (simultaneous)	150			

Abbreviations: UTKA unilateral total knee arthroplasty, SSBTKA single-stage bilateral total knee arthroplasty, SBTKA staged bilateral total knee arthroplasty, [Re] retrospective, [Pr] prospective, NA not available, Wk week, Mo month, Yr year, DTB administrative or governmental database, Asterisk patients older than 75, Double Asterisks all obese patients

Comments: 1a. Higher rate of aseptic loosening compared to the single-stage BTKA group, 1b. Higher incidence of pulmonary embolism compared to unilateral TKA. 2. Higher incidence of thromboembolic disease. 3. Congestive heart failure and acute delirium were found to be significantly more frequent in the BTKA group than in the unilateral TKA group. 4. Increased incidence of cardiopulmonary complications and confusion in the single-stage BTKA group. 5a. Surgical and wound infections less frequent in the single-stage BTKA. 5b. With respect to 3-month staged procedure, higher rate of nosocomial infections. 6. Increased incidence of myocardial infarction. All affected patients had pre-existing cardiovascular conditions. 7. Higher incidence of gastrointestinal complications in patients younger than 80 years of age in the single-stage BTKA group. Higher incidence of pulmonary complications in patients older than 80 years of age in the single-stage BTKA group. 8. A significant increase in mortality rate in the single-stage BTKA group compared to SBTKA and unilateral TKA groups was only observed in patients older than 75 years of age. 9. Increased rate of pulmonary embolism. 10a. with respect to single-stage BTKA, increased incidence of superficial wound infection. 10b. with respect to unilateral TKA, increased incidence of thrombophlebitis. 10c. with respect to unilateral TKA, increased incidence of gastrointestinal ulcers and intestinal ileus. 11. Increased risk of confusion and myocardial infarction. 12. Increased risk of thromboembolic and cardiovascular disorders. 13. Minor complication rate (urinary retention, urinary tract infection, deep-vein thrombosis, pneumonia, superficial infection, early knee manipulation for poor motion, atrial fibrillation, and admission to the hospital without monitoring in the intensive care unit) was lower in the SBTKA compared with unilateral TKA. 14a. Increased incidence of deep vein thrombosis for both bilateral TKAs compared to unilateral. No difference between single-stage BTKA and SBTKA. 14b. Increased incidence of pulmonary embolism for both bilateral TKAs compared to unilateral TKA. No difference between single-stage BTKA and SBTKA. 15. Increased rate of new onset atrial fibrillation, hypoxemia, and confusion. 16a. Increased rate of superficial and deep wound infections. 16b. Increased risk of cardiac complications (MI, acute rhythm changes, acute episodes of heart failure) and chest infections. 17a. 9,688 of all entries for BTKA (43,350) did not allow for determination of timing of one or both procedures and were therefore excluded from the subgroup analysis. 17b. Higher peripheral vascular complications, vessel/nerve complications, wound dehiscence, infection rates in the BTKA group compared with unilateral TKA group. 17c. Higher rate of DVT in the single-stage BTKA group with respect to the staged BTKA group. 17d. Higher rate of PE, adult respiratory distress syndrome, respiratory complications, acute hemorrhagic anaemia, shock, central nervous system complications, gastrointestinal complications, genitourinary complications in the BTKA group compared with the unilateral TKA group. 17e. Higher rate of PE in the single-stage BTKA group compared with the staged BTKA group. 17f. Higher incidence of adult respiratory distress syndrome, post hemorrhagic anaemia, central nervous system complications, respiratory complications, gastrointestinal complications, genitourinary complications in the staged BTKA group with respect to the single-stage BTKA group. 17g. Higher in-hospital mortality rates in the BTKA group compared with the unilateral TKA group. 18. Higher incidence of overall systemic complications (hypovolemic shock, pneumonia, confusion, uremic encephalitis, acute renal failure, ICU care, thromboembolic disease, mortality). Within the single-stage BTKA group, high risk patients had significantly greater risk of systemic complications compared with low risk patients

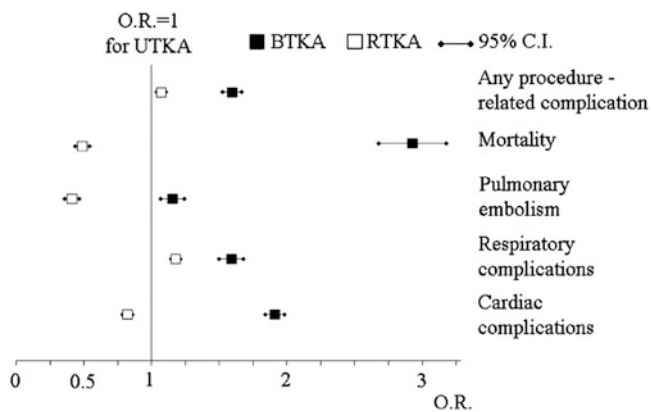


Fig. 23.3 Odds ratios (ORs) and 95 % confidence intervals (95 % CIs) for in-hospital mortality and selected medical complications in patients undergoing BTKA and RTKA. (Referent is UTKA; OR, 1.) All ORs are different from UTKA = 1. *BTKA* bilateral TKA, *RTKA* revision TKA, *UTKA* unilateral TKA (Used with permission from Memtsoudis SG, Gonzalez Della Valle A, Besculides MC, Gaber L, Sculco TP: In-hospital complications and mortality of unilateral, bilateral, and revision TKA: based on an estimate of 4,159,661 discharges. *Clin Orthop Relat Res* 2008; 466:2617–27)

Mortality

Only few studies in the literature have sufficient power to detect potential differences in mortality (Table 23.2). One study [70] reviewed 62,730 BTKAs (12,922 simultaneous, 4,354 staged 1 week apart, 4,524 staged 3 months apart, 9,829 staged 6 months apart, 31,401 staged 1 year apart) utilizing the Health Care Financing Administration's Medicare Provider Analysis and Review files between 1985 and 1990. The authors reported a 30-day mortality rate of 0.33 % for staged BTKA as opposed to 0.99 % for simultaneous BTKA ($p < 0.05$). Parvizi et al. [19] reviewed 19,861 unilateral TKAs and 2,679 single-stage BTKAs performed at their institution, reporting a 30-day mortality rate of 0.17 % and 0.49 %, respectively ($p < 0.05$). Other authors found contrasting results. Kim et al. [12] reported that the 90-day mortality rate of 2,385 sequential BTKA patients (0.3 %) and 719 unilateral TKA patients (0.7 %) was similar.

In our analysis of the National Hospital Discharge Survey from the years 1990 to 2004 [25], we found that the in-hospital mortality rate of BTKA patients (0.5 %) was higher than that of patients undergoing unilateral TKA (0.3 %). Our multivariate analysis controlling for type of surgery, age, gender, race, hospital bed size, US region, source of payment, and comorbidities revealed that the risk-adjusted mortality among patients undergoing BTKA was three times higher compared with those receiving unilateral TKA (Fig. 23.3). The discrepancy in mortality between BTKA and unilateral TKA was confirmed in our most recent analysis of nationally representative data collected for the

Nationwide Inpatient Sample [45]. In both studies in-hospital mortality among BTKA patients was higher despite the fact that this population was younger and overall healthier than unilateral TKA recipients.

Cardiac Complications

Several authors have expressed concern about a higher risk of cardiac complications in patients undergoing single-stage BTKA. The most frequently encountered cardiac complications include myocardial infarction (MI), arrhythmias, angina, and congestive heart failure [10, 11, 38, 67, 71]. Bullock et al. [16] observed myocardial ischemia to be 5 times more frequent in 255 simultaneous BTKA patients than in 514 unilateral TKA patients. Other authors encountered similar findings: the rates of myocardial infarction and arrhythmias were 4–6 times more frequent in patients undergoing single-stage BTKA (15.8 % and 24.5 %, respectively) than in patients undergoing unilateral TKA (3.7 % and 6.1 % respectively) [67, 71]. Our institutional experience [42, 72] demonstrated that single-stage BTKA is associated with a significantly higher risk of cardiovascular complications (mainly arrhythmias, congestive heart failure, and DVT) especially in patients with medical comorbidities such as pulmonary hypertension, congestive heart failure, chronic pulmonary disease, and renal disease. These findings are probably explained by the stress imposed by longer operative times, larger fluid shifts, a more significant hyperadrenergic state, risk for anaemia, and overall higher invasiveness of BTKA compared to unilateral TKA. Patients with reduced end-organ reserve and thus decreased ability to compensate for these insults may be at especially high risk [45].

Pulmonary Complications Including Thromboembolism

Fat and pulmonary emboli are more frequent in patients undergoing single-stage BTKA than in those undergoing unilateral TKA. Some authors have proposed using a fluted intramedullary rod, slow rod insertion technique, and overdrilling the entry point for the guide rod [33, 73, 74] to reduce the risk of forcing medullary contents into the venous system. However, Lane et al. [18] concluded that even when no intramedullary rods are used during surgery, fat embolism is still a concrete threat.

Pulmonary embolism seems to be associated with increased operating time of single-stage BTKA, the cementing of the components, the surgical intervention at both lower extremities, and a prolonged duration of relative immobility [75]. Indeed, all of the aforementioned events

contribute to trigger the Virchow triad of venous stasis and turbulence, endothelial injury, and Hypercoagulability [76]. Our study of in-hospital complications of TKA surgery [25] based on an estimate of 4,159,661 discharges in the USA from 1990 to 2004, demonstrated a 50 % increased risk of pulmonary embolism in patients undergoing BTKA as opposed to unilateral TKA. These observations were made despite a more favourable comorbidity profile and younger age among patients undergoing BTKA. A comparable trend was also observed by Barrett et al. [77], who reported the adjusted risk of PE was 80 % higher in the BTKA group, and by Restrepo et al. [78], who reported an increased risk of PE in single-stage BTKA patients (odds ratio of 1.8). Although the majority of studies alert about a higher risk of pulmonary embolism in patients undergoing single-stage BTKA, one investigation reported a similar rate of asymptomatic deep venous thrombosis (41 %) in 116 single-stage BTKA patients and 111 unilateral TKA patients not receiving thromboprophylaxis [79].

Given the fact that the majority of studies have observed a higher risk of pulmonary complications including thromboembolism, it seems prudent to screen patients who are suspected of having increased pulmonary pressure or right heart dysfunction, including patients with sleep apnea, and those with a history of pulmonary embolism, and consider them at high risk. This is because these conditions may be associated with higher impedance to venous return due to increases in right heart pressures, especially after additional increases in pulmonary vascular resistance brought upon by embolizing debris after bilateral procedures [80–83]. In addition, we advocate routine thromboprophylaxis with Coumadin in patients undergoing single-stage BTKA surgery.

Post-operative Confusion

There seems to be agreement on the higher rate of post-operative confusion after single-stage BTKA compared to unilateral TKA [18, 25, 84, 85]. The cause for this complication seems to lie within higher degree of systemic inflammation and higher rates of fat and debris embolization [18, 86]. Some researchers have conducted intraoperative hemodynamic monitoring, electroencephalography, and direct ultrasound imaging of the carotid artery in patients undergoing bilateral lower limb replacements, observing debris embolization into the arterial circulation especially upon tourniquet deflation immediately after the second of two sequential arthroplasty procedures [86, 87].

Potential Increase in Wound Infection Rate

The literature reports contrasting opinions regarding wound infection rates following single-stage BTKA and unilateral TKA [1, 30, 69]. Those who have observed a higher infection rate in single-stage BTKA surgery [1, 30] blame the longer operating times, increased number of medical personnel in the operating room, and no re-scrubbing, no re-draping, and no instrument change for the second knee arthroplasty.

We studied the deep and superficial wound infection rates 1 year after single-stage bilateral total hip arthroplasties performed with 1 or 2 sets of sterile instruments [88]. The rate of infection in 271 patients who had a new sterile setting for the second hip was similar to that of 294 patients who had both hips done using the same instruments ($p \sim 1.0$).

Some authors suggested that BTKA surgery has a lower risk of perioperative infection in comparison to unilateral TKA. A large retrospective cohort study on almost 4,000 patients [10] observed a significantly lower rate of superficial infection risk for BTKA (0.3 %) compared to unilateral TKAs (0.8 %) ($p = 0.0243$). Similarly, our study on in-hospital complications of over four million TKAs in the USA showed that despite the higher rate of obesity in patients undergoing BTKA (8.3 % vs. 6.3 % in unilateral TKA patients), those undergoing unilateral TKA had higher rates of procedure-related in-hospital infection (0.1 % vs. 0.2 % in the unilateral TKA group) [25]. This may be explained by the fact that the latter group had an increased prevalence of other comorbidities, some that are linked to an increased risk of infection, i.e. diabetes [89].

Use of Allogenic Blood Transfusions

Predictably, the incidence of post-hemorrhagic anaemia is greater after single-stage BTKA than unilateral TKA. Utilizing nationally representative data we found the incidence of post-operative anaemia to be around 28.6 % in BTKA and 15.3 % in unilateral TKA patients [25]. Besides twice the blood loss related to the second procedure, Bould et al. [90] showed a prolongation in the prothrombin time, activated partial thromboplastin time, and thrombin time after release of the first tourniquet, hypothetically due to tissue trauma, tourniquet application with decrease in clotting factors, and perioperative hypothermia.

The increased risk of allogenic blood transfusions after single-stage BTKA has been reported to be as high as 17-fold [15, 18, 42, 91]. In order to limit the need for allogenic

blood transfusion, Breakwell et al. [92] recommended the use of a cell saver. In their study of 33 patients undergoing simultaneous BTKA randomized to receive allogenic blood only, or a combination of collected and re-infused blood, an average of 1,000 ml of drainage blood was salvaged in the study group, resulting in a significant reduction in allogenic blood requirements from 6.3 to 3.8 units in total ($p = 0.002$).

Use of Tertiary Rehabilitation Centers

There is an increased proportion of patients undergoing single-stage BTKA surgery that are discharged to an acute/subacute rehabilitation facility, than following unilateral TKA surgery [9, 17, 18, 25, 64, 67]. In our study reporting on the trends of TKA surgery in the USA between 1990 and 2004, we observed that 37.2 % of 153,259 BTKA patients in comparison to 19.6 % of 3,672,247 unilateral TKA patients were discharged to short- or long-term facilities [25]. The reason for this seems to lie not solely in the slower post-operative mobilization of patients undergoing BTKA but also in surgeon, physical therapist, and social worker expectation that dedicated rehabilitation after the hospital stay would be more frequently necessary in BTKA compared to unilateral TKA patients. The decision to transfer a patient to a rehabilitation facility is strongly affected by the patient ability to ambulate at the time of discharge. This difference can be accounted for by the fact that patients undergoing unilateral TKA most commonly have only unilateral OA, and thus may be less affected in the ability to ambulate. This is in contrast to BTKA patients who have bilateral disease.

Timing of Surgery for BTKA

There is evidence that suggests that BTKA surgery performed during the same hospitalization should be performed under a single anesthetic (single-stage). We analyzed the perioperative outcomes of unilateral TKA and BTKA patients using 670,305 admissions in the Nationwide Inpatient Sample (NIS) between 1998 and 2006 [45]. Among patients undergoing BTKA during the same hospitalization, 74.8 % were performed under the same anesthetic, while the remainder was performed on separate days of the hospital admission (average: 3.6 days apart). Procedure related complications were less frequent in single-stage BTKA patients ($p < 0.0001$). Such complications included: central nervous system, peripheral vascular, respiratory, gastrointestinal, genitourinary, wound dehiscence, infection, and others. For all mentioned categories, staged procedures during the same hospitalization had a significantly higher incidence of complications. However, venous thrombosis

and pulmonary embolism occurred more frequently among single-stage procedure recipients [1.48 % vs. 1.22 % ($p = 0.0002$) and 0.89 % vs. 0.77 % ($p = 0.0218$), respectively]. No statistical difference in the rates of in-hospital mortality was seen between groups.

Ritter et al. [70] studied the ideal timing between surgeries for BTKA patients. Their data from the Health Care Financing Administration's Medicare Provider Analysis and Review files in the USA between 1985 and 1990 included information on 12,922 single-stage BTKAs, 4,354 staged BTKAs (6 weeks apart), 4,524 staged BTKAs (3 months apart), 9,829 staged BTKAs (6 months apart), and 31,401 staged BTKAs (1 year apart). They observed that no single group had the lowest complication rate on all measures. Surgery-related complications (i.e. wound dehiscence, wound infection, post-operative haemorrhage, and mechanical complications of orthopedic devices) were almost 50 % higher in all staged BTKA groups compared with the single-stage BTKA group. Vascular complications were lowest in the 6-week group and highest in the 1-year group (4.1 % and 6.8 %, respectively). Nosocomial infections were lowest in the 3-month staged BTKA group ($p < 0.05$). Wound infections were significantly lower in the simultaneous BTKA group (0.05 %). In terms of mortality, despite the very low cumulative 30-day, 3-month and 6-month mortality rates (1 %, 1.5 %, and 2 %, respectively), simultaneous BTKA patients were almost 50 % more likely to die. The authors concluded that none of the bilateral groups performed categorically better than the others, although 3-month staged BTKA was associated with the most favourable profile. The previously mentioned data and suggestions are particularly important in light of findings by other authors, who reported that patients with equally severe bilateral knee osteoarthritis have a 75 % probability of having both knees replaced within 1 year of each other [93].

Recommendations for Patient Selection

In view of the presented facts and figures and in order to diminish the rate of perioperative life-threatening complications of surgery and mortality for this elective procedure, it seems reasonable and prudent to carefully select patients that are candidates for BTKA surgery. We conducted a study aiming at identifying risk factors for morbidity and mortality following BTKA surgery using data from the Nationwide Inpatient Sample [81]. Of the 42,003 entries identified, representing an estimated 206,573 elective BTKA procedures performed in the USA between 1998 and 2007, 9.5 % developed major complications or mortality during their hospitalization. Increasing age was an independent risk factor for major

Table 23.3 Contraindications to single-stage BTKA

	Absolute contraindication	Relative contraindication	Suggested further evaluation
Extreme age (>80)	X		
ASA class: 3 or greater	X		
Obesity		X	Echocardiography
Sleep apnea		X	Echocardiography
COPD		X	Echocardiography
History of thromboembolism		X	Echocardiography

morbidity and mortality. Patients younger than 45 years were half as likely to have a major complication or mortality with respect to patients in the age group between 45 and 64 years (odds ratio:0.49—confidence interval 0.30;0.81). Comparatively, the risk for patients aged 65–74 and greater than 75 years rose significantly (odds ratio: 1.81, confidence interval 1.67–2.30 and odds ratio: 2.52, confidence interval 2.30–2.77, respectively). Advanced age as a risk factor has been further supported by findings published by other authors [19, 94]. This is likely associated with the fact that older patients have a physiologic decline in end organ reserve putting them in a more vulnerable position. Age as a risk factor and its consideration when contemplating BTKA becomes especially a problem when considering that a large number of joint arthroplasty recipients falls into this category. Male gender was associated with increased odds for adverse outcome (odds ratio: 1.5, confidence interval 1.44–1.66); however, reasons for this finding have to remain speculative. A number of comorbidities were identified as independent risk factors for major complications and mortality: pulmonary hypertension, congestive heart failure, fluid and electrolyte abnormalities, cardiac valve disease, renal failure, neurologic disease, coagulopathies, and chronic lung disease. Specifically, pulmonary hypertension and congestive heart failure were the most significant comorbidities associated with increased odds (odds ratio: 4.10 and 5.55, respectively) for adverse outcome.

Our experience, body of research and review of the literature has lead to the creation of guidelines for the selection of appropriate candidates for single-stage BTKA, in a desire to reconcile benefits and concerns for safety (Table 23.3).

Although conclusive evidence is limited, the literature suggests that the following points should be considered when contemplating single-stage BTKA:

1. *Exclusion based on age:* The findings of several authors [10, 19, 26, 67, 71, 72, 94–97] support that single-stage BTKA surgery in patients of extreme age should be avoided.
2. *Exclusion based on American Society of Anesthesiologists (ASA) classification:* The findings of several authors [26, 42, 69, 72, 81, 98] support the exclusion of patients with significant end organ dysfunction, i.e. an ASA physical status of 3 or greater.

3. *Exclusion based on specific comorbidities:* Patients at risk for occult derangements of pulmonary hemodynamics and right heart dysfunction (i.e. the morbidly obese and those with sleep apnea, chronic obstructive pulmonary disease, and previous pulmonary embolism) should undergo cardiopulmonary evaluation with echocardiography to rule out significant pre-existing increases in pulmonary artery pressures, which may predispose patients to increased morbidity and mortality. Besides pulmonary hypertension, congestive heart failure, and chronic lung disease, other comorbidities should be used as exclusion criteria, including coronary artery disease, renal failure, neurological disease, hepatic dysfunction, and coagulopathies.

Furthermore, recognizing the need for guidance on the subject, a national group of experts participated in an elaborate consensus project to produce guidelines on the peri-operative management of patients requiring single-stage BTKA [105]. These represent a consensus of specialized institutions.

Summary

In our experience and with the awareness of the previously mentioned recommendations, single-stage BTKA represents a valid option for the treatment of severe pain produced by bilateral knee osteoarthritis in the carefully selected patient. The advantages include good clinical results, the use of a single anesthetic, a shorter overall surgical time, and similar or less pain with respect to unilateral TKA (especially after post-operative day 1), reflected in a lower use of narcotics. Additionally, total recovery time compared with staged BTKA is faster, predictably accelerating return to everyday life and work. Patient satisfaction is qualitatively and quantitatively at least equivalent to that of unilateral TKA, with the overwhelming majority of patients who have experienced single-stage BTKA declaring they would opt for the same procedure again. Finally, cost-effectiveness of single-stage BTKA represents a major advantage of the procedure, with overall savings between 18 % and 58 % compared with the cost of staged procedures.

On the other hand, the disadvantages of single-stage BTKA must be considered when evaluating a potential candidate. The higher mortality rate in single-stage BTKA compared with unilateral TKA patients represents the most feared outcome. Although most studies in the literature do not reach significant power to actually detect potential differences in mortality, the latter seems to be significantly increased in single-stage compared to unilateral procedures. Cardiac complications, in particular myocardial infarctions, arrhythmias, angina, and congestive heart failure are more prevalent in single-stage BTKA patients. These findings are possibly related to stress imposed by longer operative times, larger fluid shifts, a more significant hyperadrenergic state, risk for anaemia, and overall higher invasiveness of BTKA compared with unilateral TKA. Pulmonary complications including thromboembolism and post-operative confusion are also a concern when selecting patients for single-stage BTKA. Greater wound infection rates seem to be controversial. Further drawbacks of single-stage BTKA include the increased use of allogenic blood transfusions. Finally, the greater use of tertiary rehabilitation centers might be regarded as a disadvantage of BTKA. While an increased proportion of patients undergoing single-stage BTKA surgery are discharged to an acute/subacute rehabilitation facility compared to unilateral TKA recipients, patients belonging to the latter group appear to be more likely readmitted for post-operative knee stiffness.

In light of the presented data and according to our experience at the Hospital for Special Surgery, single-stage BTKA represents a valuable option to restore knee function and well-being in patients with bilateral knee osteoarthritis. However, despite the low prevalence of life-threatening complications, thorough patient selection is advised, with the ideal candidate for single-stage BTKA being motivated, young, and healthy. The need for prospective randomized studies remains crucial to further support of clinical recommendations for patient selection.

Summary Bullet Points

- Bilateral total knee arthroplasties can be performed during a single surgical session, sequential or simultaneous, or staged during different surgeries
- Single-stage bilateral knee arthroplasty may be associated with reduced hospital costs and the advantage of a single hospitalization.
- Single-stage surgery may be associated with increased risk for perioperative complications in the unselected patient population.
- In order to reconcile higher risk with the benefits of single-stage bilateral knee arthroplasty institutions and clinicians may want to consider the utilization of strict screening criteria to guide patient selection.

Case Study

A case study for this chapter is included in Appendix M at the end of this book.

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