Consensus Statement from the Consensus Conference on Bilateral Total Knee Arthroplasty Group

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Abstract

Background Controversy exists regarding many aspects of decision making pertaining to same-day versus staged bilateral TKA (BTKAs), including patient selection, perioperative management decisions, and other important choices.

Questions/purposes In the absence of suitable randomized trials, we sought to determine areas of consensus among national experts on the following questions: (1) What are the comparative risks of same-day BTKAs compared with unilateral TKA (UTKA) and staged BTKAs? (2) Who should be considered an appropriate

candidate for same-day BTKAs? (3) What constitutes appropriate workup and perioperative management for BTKAs? (4) What is the optimal time between procedures if same-day BTKAs are not deemed appropriate? (5) Are there orthopaedic or rehabilitation considerations for BTKAs that might outweigh medical contraindications?

Methods In the setting of a consensus conference of national experts in orthopaedic surgery, anesthesiology, perioperative medicine, and epidemiology, the major questions surrounding same-day BTKAs were addressed by using an extensive literature review and the modified

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Delphi process. The process concluded with a meeting of participants and formulation of consensus statements.

Results Eighty-one percent of participants agreed that BTKAs are more invasive and complex procedures associated with increased risk for perioperative adverse events compared with UTKA in an unselected group of patients. The consensus group agreed that physicians and hospitals should consider using more restrictive patient selection criteria and exclude those with a modified cardiac risk index greater than 3 to mitigate the potentially increased risk. The majority of the group agreed that perioperative assessment and management should reflect the higher level of acuity of same-day BTKAs. Eighty-one percent of participants agreed that if a patient is not deemed a candidate for same-day BTKAs, a second TKA should be scheduled no sooner than 3 months after the first. The entire group agreed that when there is a conflict between the orthopaedic need and the medical adequacy of same-day BTKAs, the medical concern for the patient's safety should prevail over the orthopaedic need.

Conclusions Experts perceived that same-day BTKAs increase medical risk, and thus a systematic approach to the management of patients should be taken to minimize complications.

Introduction

The number of TKAs performed in the United States has been steadily increasing. Most recently, approximately 6% of all TKAs performed were bilateral TKAs (BTKAs) [32]. Considerable controversy exists surrounding various aspects of the practice of same-day BTKAs [28, 39]. Among many discussed factors, proponents of same-day BTKAs point to overall decreased rehabilitation times and the need for only one hospitalization [20], while skeptics quote factors such as increased need for blood transfusions and exposure of organ systems to increased perioperative insults including the embolization of marrow and bone debris [9, 31–34]. Several published studies suggest that same-day BTKAs are associated with increased risk for morbidity and mortality compared with unilateral TKA (UTKA) [14, 29, 39], but no adequately powered prospective, controlled trials or other definitive publications exist that allow for comparison of same-day with staged BTKAs. Complicating matters is a lack of agreement on the question if risks associated with same-day BTKAs should and can be compared with the aggregate risk of the two operations in staged BTKAs, thus leaving most clinicians, such as the participants of this group, to compare same-day BTKA approaches with more available UTKA data.

In the absence of adequate information, clinicians caring for patients with bilateral knee arthritis have to balance the benefits of one hospitalization and patient convenience

with their concern for patient safety. To date, no consensus exists to aid physicians and their patients in their decision-making process regarding whether to proceed with same-day BTKAs or staged BTKAs.

Recognizing this void, a multidisciplinary group of experts was assembled with the goal of reviewing the available literature, forming a consensus on the current state of knowledge, and providing recommendations on the care of patients undergoing BTKAs. A secondary goal was the identification of priority areas for further study. Appropriate methodology for conducting a consensus was followed. This article represents a summary statement of the consensus process and its results pertaining to the five questions the group identified as important, which were:

(1) What are the comparative risks of same-day BTKAs compared with UTKA and staged BTKAs? (2) Who should be considered an appropriate candidate for same-day BTKAs and what are the medical contraindications? (3) What constitutes appropriate workup and perioperative management for BTKAs? (4) What is the optimal time between procedures if same-day BTKAs are not deemed appropriate? (5) Are there orthopaedic or rehabilitation considerations for BTKAs, and do they outweigh medical contraindications?

Materials and Methods

In September 2011, a seven-member, interdisciplinary steering committee of orthopaedic surgeons, anesthesiologists, perioperative internists, and an epidemiologist (Appendix 1; Supplemental materials are available with the online version of CORR.) was formed with the goal of identifying numerous topics related to BTKAs that represented major areas of controversy. The goal was to formulate actionable statements that would provide guidance to physicians caring for patients undergoing BTKAs. After extensive review and discussion, topics were categorized, focused into five major areas of interest, and phrased in the form of questions, as articulated above.

After this step, the steering committee identified a group of 32 individuals who, based on their publication record, academic interest, current practice, and national standing in their respective fields, were considered experts in the field of perioperative care and orthopaedic surgery with a focus on BTKAs.

An invitation to participate in a consensus process was extended to these individuals, who represented 16 different institutions throughout the country, with the additional request of suggesting additional participants and topics for discussion.

As a consequence, eight more participants were identified and invited bringing the total to 40. Next, individuals

were asked to summarize the current state of knowledge on each of the topics in the form of a state-of-the-art white paper. These white papers were intended for use during the consensus process and have not been published elsewhere. The format included an introduction of the problem, an overview of the available literature, a conclusion, and a recommendation for practitioners. In addition, the authors were asked to identify gaps in research and suggest studies that would fill this void. Each author was asked to select two reviewers from separate institutions from the group of participants, ideally with differing perspectives, who were tasked with providing critique and suggestions for amendment of the original document. This process resulted in a peer-reviewed, revised version of each white paper.

All white papers were sent to the entire group of participants. Using the revised Delphi process [23] to achieve consensus, each participant was asked to anonymously comment on the following questions: (1) Are there published articles or bibliographic sources that you believe are important and that have not been included in the literature review? If yes, please list. (2) Do you agree with the main conclusions of the white paper? If no, please explain. (3) Do you agree with the main recommendations of the white paper? If no, please explain. (4) Would you like to add one or more recommendations? If yes, please list. (5) Do you agree with the suggestions for new studies? If no, please explain. (6) Would you suggest one or more study or studies? If yes, please add. (7) Are there one or more specific controversies around the issue addressed by this paper that you would like to highlight or reiterate? If yes, please list.

Literature Review

To supplement the literature review performed by the authors of the white papers and associated with the consensus process, an independent senior librarian (TR) performed a literature search using the following search string in Ovid PubMed: “((BILATERAL)) AND ((knee arthroplasty) AND (mortality OR morbidity OR safety OR adverse effects OR complications)) AND ((“2005/01/01”[PDat]: “3000/12/31”[PDat]))”. This search took into account the availability of systematic reviews on the topic summarizing data published before 2005 and resulted in a reference list of 244 articles. Of this group, 170 articles did not pertain to the discussed subjects and were excluded. The results of this literature search (74 publications) and the anonymously collected comments were circulated back to the original authors of the white papers. The author was asked to crosscheck the reference list for any missing publications and incorporate any comments made into the article. Comments not incorporated were listed as stated in

an appendix to each white paper. The response rate for comments was 58%.

The final versions of the white papers were sent to all participants and all were invited to attend a 2-day consensus meeting, which was held in New York City on September 8 and 9, 2012. Twenty-nine participants were able to attend the meeting, although all others had received the white papers and were given the opportunity to participate. The goal of this conference was to finalize the consensus on each topic through discussion of remaining issues in focus groups, formulate consensus statements, and discuss those in a plenary session. A final version of each consensus statement was brought before the group, which using an electronic voting system was asked to agree or disagree.

Participants and organizers of the consensus process and meeting were aware of the limited scope of this endeavor. First, only a limited number of experts from overwhelmingly high volume and academic institutions participated owing to logistic and financial restrictions thus limiting the generalizability of this group’s collective clinical and scientific experience. Further, although the influence of strong opinions may represent a limitation in any process seeking to gain consensus on a topic, our approach was designed with the goal to allow for the formation of the major portion of this consensus before the actual meeting, thus leaving only smaller matters to be resolved at the actual conference. Finally, this consensus process was meant to provide a starting point for a wider discussion on this topic and should not be viewed as an attempt to provide definitive answers.

Results

The results presented subsequently represent the final consensus statements that were reached after extensive review of the white papers and incorporation of the comments raised during the consensus meeting. The questions of interest are presented followed by the consensus statement and a comment section, which includes a summary of the literature review.

- (1) What are the comparative risks of simultaneous same-day BTKAs compared with UTKA and staged BTKAs?

Consensus Statement

The majority of the group (81%) agreed that same-day BTKAs were associated with higher risk of complications when compared with unilateral or staged TKAs. All of the

participants (100%) agreed that more careful patient selection and deliberation of patient-specific risk factors for morbidity and mortality are warranted for patients being considered for same-day BTKAs. Ninety-three percent of participants acknowledged that there is a need for a multicenter study group that can pursue further research related to BTKAs in general and the associated risks of same-day BTKAs in particular.

Comment and Supporting Literature

The literature on this subject lacks Level I evidence. The majority of publications including two meta-analyses and some large database studies suggest increased risk associated with BTKAs compared with UTKA [14, 28–32, 39, 41, 46, 47]. Some smaller studies suggest no increased risk with same-day BTKAs compared with UTKA [1, 20, 27]. No large prospectively randomized study is available to compare same-day with staged BTKAs [6, 9, 14–16, 26, 40, 44, 50, 51].

(2) Who should be considered an appropriate candidate for BTKAs and what are the medical contraindications?

Consensus Statement

The group agreed that same-day BTKAs confer greater risk for mortality and for some, but not all, postoperative medical complications. In consideration of each of the major postoperative medical complications, important patient-related factors should be considered by the clinician when recommending same-day BTKAs. The majority of participants (85%) agreed that at a minimum, patients scoring 3 or higher on the revised cardiac risk index presented by Lee et al. [21] (which takes into account the invasiveness of the procedure, history of myocardial ischemia, heart failure, cerebrovascular events, renal failure [creatinine > 2 mg/dL], and insulin-dependent diabetes mellitus) should be excluded from undergoing same-day BTKAs. Realizing that this index may estimate the risk of unacceptably high incidence of cardiac complications but may not be suitable for more conservative patient selection in the setting of BTKAs, the majority of the group (63%) preferred the use of the following exclusion criteria based on the only published guidelines [50]: (1) patients older than 75 years; (2) all patients with an American Society of Anesthesiologists Class III condition; (3) active ischemic heart disease (positive stress test or a history of anginal equivalents); (4) decreased left ventricular function (left ventricular ejection fraction < 50%). Patients with symptoms of dyspnea on exertion, shortness of breath, or poor functional capacity

should have a preoperative echocardiogram; (5) pulmonary disease (moderate to severe pulmonary hypertension, oxygen-dependent pulmonary disease, oral steroid-dependent asthma, exercise-limiting chronic obstructive pulmonary disease); (6) morbid obesity (body mass index > 40 kg/m²); (7) renal insufficiency (creatinine > 1.6 mg/dL); (8) chronic liver disease (functional impairment in liver function and/or ascites, Child's Class B or greater); (9) poorly controlled diabetes mellitus; (10) cerebrovascular disease with a history of a previous stroke; and (11) major peripheral vascular disease involving the lower extremities with stents or vascular bypass.

On the specific criteria, only 56% of participants believed age should be an exclusion criterion based on the argument that biologic rather than absolute age should be taken into consideration; however, others expressed that the physiologic decline in end-organ function that occurs with age justifies such an exclusion even in healthy individuals. Ninety-three percent favored avoiding same-day BTKAs in patients who have an American Society of Anesthesiologists classification of 3 and higher. The same proportion (93%) believed patients with ischemic cardiac disease should not undergo same-day BTKAs. A cutoff of BMI of 40 kg/m² was seen by 64% as a reason to avoid same-day BTKAs. Twenty-nine percent favored a cutoff less than 40 kg/m². Seventy-five percent of participants agreed with a creatinine cutoff of 1.6 mg/dL in patients with renal dysfunction.

Comment and Literature Review

There was general agreement that patients with greater comorbidity burden are at increased risk for adverse outcomes and that patient selection was important. Considerable time was spent on the discussion of some of the specific criteria as outlined previously. Reviewing the literature, it was believed that the risk of perioperative complications was greater for older patients and for patients with considerable medical comorbidities, particularly those with a history of cardiopulmonary disease [2, 4, 27–31, 33, 34, 36, 43, 44, 53].

(3) What constitutes appropriate workup and perioperative management for BTKAs?

Consensus Statement

Seventy-nine percent of participants agreed that although unilateral TKAs usually are classified as medium-risk procedures (according to the American College of Cardiology/American Heart Association Perioperative Cardiovascular

Evaluation [11]), BTKAs should be considered high-risk procedures, necessitating a more thorough preoperative workup. A majority of participants (63%) supported that given the known associations with adverse outcomes, patients should be screened carefully for cardiorespiratory comorbidities. Depending on the morbidity status of the patient, numerous diagnostic modalities should be considered, including echocardiography, estimation of pulmonary pressures, spirometry, exercise testing, and pulmonary gas exchange diffusing capacity of the lung for carbon monoxide (DLCO). Ninety-seven percent of participants recommended that consideration should be given to having a medical service follow patients postoperatively given the elevated incidence of cardiopulmonary complications.

Comment and Literature Review

There is a lack of literature on the management of patients undergoing BTKAs. Thus recommendations are extrapolated from other literature as suggested for higher-risk interventions. Hospitals may consider developing pathways for eligibility, testing, and perioperative management of patients having BTKAs with a view to improving outcomes [19].

Preoperative Testing

There is a lack of evidence that aggressive preoperative management changes outcome in general. However, given the nature of the surgery and the expected pathophysiology, preoperative echocardiographic assessment of the heart should be considered given the incidence of right heart strain and pulmonary hypertension after same-day BTKAs [31]. If possible, pulmonary arterial pressures should be estimated, right heart function should be characterized, and other abnormalities should be documented.

Given the apparent association between pulmonary disease and complications and simultaneous BTKAs, a thorough pulmonary history should be documented. Signs or symptoms of pulmonary disease should be assessed with a focus on gas exchange (DLCO), respiratory mechanics (spirometry), and cardiopulmonary interactions (exercise testing). Routine chest radiographs should be obtained in view of the association between interstitial lung disease and inflammatory arthritis [42].

Routine laboratory investigations may include chemistry, HbA1C, albumin and liver function testing, a complete blood count, and testing of the coagulation system. Abnormalities should be further investigated (Table 1).

Autologous blood donation may be considered given the potential for significant blood loss, but this is very controversial [7, 10, 35].

Table 1. Suggested preoperative management of same-day BTKAs as indicated by the patient's cardiopulmonary history

Suggested management	Comments
Echocardiography	Structural and functional assessment and documentation of abnormalities, assessment of pulmonary arterial pressures, characterization of right-heart function
Pulmonary history	Signs of pulmonary history; if history is significant for signs and symptoms of pulmonary disease, further testing should be considered
Carbon-monoxide diffusion capacity (DLCO)	Assessment of gas exchange
Spirometry	Assessment of respiratory mechanics
Exercise testing	Assessment of cardiopulmonary interaction
Routine chest radiograph	Association between interstitial lung disease and inflammatory arthritis
Routine laboratory investigations	Chemistry, electrolytes, HbA1C, albumin, liver function test, complete blood count, coagulation tests

Intraoperative Management

Although there are strong theoretical advantages for performing BTKAs with a regional anesthetic technique [47], conclusive studies are lacking [24], and the anesthetic approach should be individualized.

In addition to standard monitoring, invasive arterial blood pressure monitoring should be considered. Large-bore intravenous access should be obtained. Hypercapnia and hypoxemia should be avoided given their effects on pulmonary arterial resistance.

It is not advisable to perform BTKAs in patients at high-risk for cardiopulmonary complications; however, if such a decision is made, consideration should be given for a modality to monitor right heart performance and/or pulmonary pressures including transesophageal echocardiography or pulmonary arterial catheter placement. The latter does not appear to provide benefit in routine BTKAs [18].

Intraoperatively, the use of tranexamic acid may be considered to reduce blood loss [25]. Tourniquet release may be timed to optimize hemostasis [49]. Thorough assessment of a patient's condition should be performed after completion of the first knee surgery if sequential surgery is performed. Concerning features including evidence of hypoxemia or hypotension should warrant consideration of abandoning the second arthroplasty. Drainage from the first knee should be monitored during the second arthroplasty as a measure of blood loss and a guide to fluid or blood replacement. Wrapping the first knee with a compressive bandage also may be considered to prevent contamination and to aid with hemostasis (Table 2).

Table 2. Suggested intraoperative management of same-day BTKAs

Suggested management	Comments
Individualized anesthetic approach	Theoretical advantages for BTKAs with regional anesthetic technique, but conclusive studies are lacking; individualized anesthetic approach
Standard monitoring plus invasive arterial blood pressure	ECG, pulse oximetry, noninvasive blood pressure, capnography, ventilatory monitoring as applicable; invasive arterial blood pressure
Large-bore intravenous access	
Avoid hypercapnia and hypoxemia	Effect on pulmonary arterial resistance
Monitoring right heart performance and pulmonary pressure	In patients with increased risk for cardiopulmonary complications transesophageal echocardiography (TEE) or pulmonary arterial catheter placement
Tranexamic acid	Intraoperative administration of tranexamic acid may be considered to reduce blood loss
Timing of tourniquet release	Strategy to optimize hemostasis
Thorough assessment of patient condition after completion of first knee surgery	If concerning features appear after the first surgery (hypoxemia, hypotension), abandoning the second arthroplasty should be considered.
Monitoring drainage from the first knee during second arthroplasty	Must be taken into consideration for fluid and blood replacement
Wrapping the first knee with compressive bandage during second arthroplasty	Preventing contamination and aiding hemostasis

BTKA = bilateral total knee arthroplasty.

Postoperative Management

After same-day BTKAs, admission to an environment in which the patient's condition can be closely monitored is advisable given the risk of hemodynamic instability and the potential requirement for intensive care [37, 38].

Attentive postoperative medical management is indicated in these patients including laboratory testing, assessment of organ function, and pain management.

A blood-salvaging system should be considered to optimize blood management [5]. Venous thrombosis prophylaxis should be administered routinely. There may be a role for perioperative hydrocortisone or other drugs in decreasing inflammatory markers although the effect of such modulation on clinical outcome is still unknown [17].

Consideration should be given for cardiorespiratory monitoring and observation in an advanced care setting such as a

step down unit or recovery room of all patients for 12 to 24 hours after surgery. Consideration also should be given to having a medical service follow patients postoperatively given the elevated incidence of complications.

(4) What is the optimal hiatus between procedures if simultaneous BTKAs are not deemed appropriate?

Consensus Statement

Recommendations can be made only on theoretical grounds because there is a lack of specific evidence. Given available data, however, 81% of participants agreed that if a patient is not deemed a candidate for same-day BTKAs, a second TKA should be scheduled for 3 months or later. Ninety-six percent of participants agreed that staging within one hospitalization should not be routinely performed and only considered in rare circumstances such as severe bilateral lower extremity deformity. The latter approach should be taken only after extensive deliberation of risks and benefits.

Comment and Literature Review

There is a paucity of data on the topic of appropriate timing between stages for staged BTKAs, and no definitive conclusions can be drawn.

Despite inconclusive data, some evidence suggests staging BTKAs during the same hospitalization or within 3 months of the first surgery may be associated with greater risk of mortality and complications. It remains debatable if rapid staged surgery (2–10 days apart) should be used in patients who are not deemed candidates for same-day surgery [12, 13, 22, 31, 40, 45, 52].

(5) Are there orthopaedic and/or rehabilitation indications for BTKAs and do they trump medical contraindications?

Consensus Statement

The entire group (100%) agreed that when there is a conflict between the orthopaedic need and the medical adequacy of same-day BTKAs, the medical concern for the patient's safety should prevail over the orthopaedic need.

The creation of a multidisciplinary physician panel may be useful when assessing adequacy of same-day BTKAs for a given patient.

When deciding against same-day BTKAs, surgeons also may want to discuss that recovery from unilateral surgery may be affected by the symptoms of the nonsurgically

treated knee. Ninety-three percent of participants agreed that addressing the contralateral joint in cases of substantial length discrepancy early (ie, before significant limitations develop) to provide adequate surgical outcomes would be feasible.

Comment and Literature Review

No literature is available focusing on the role of severe preoperative deformity as an indication for same-day BTKAs and the debate has been dominated by concerns regarding patient safety. This debate assumes that patients who are candidates for same-day BTKAs have disabling arthritic pain affecting both knees, although this assumption has frequently been questioned. However, on some occasions, the surgeon may feel compelled to recommend a bilateral same-day operation based only on the orthopaedic condition of a patient. Some of these orthopaedic conditions include: the presence of severe bilateral deformity in the coronal and/or sagittal planes, resulting in functionally short bilateral lower extremities, and the presence of severe incapacitating bilateral knee pain. The impact of obesity on rehabilitation also should be considered [8, 48].

The recovery period for patients who had same-day BTKAs was comparable to that of patients who underwent UTKA in one study [54]; however, this generally is not agreed on.

The safety of same-day BTKAs in obese patients is supported by several publications [3, 8, 48], but the literature is insufficiently robust for general recommendation on the subject.

Perspectives for Future Studies

The consensus group agreed that there was lack of definitive evidence in the available literature regarding many topics, in particular the safety of same-day versus staged BTKAs. Participants agreed that a randomized controlled trial on this topic may not be feasible, and that additional knowledge would have to come from multicenter registries and targeted database studies using advanced simulation methods. The group also suggested targeted clinical studies of the mechanisms of adverse events in this patient population, and that more research is needed in the areas of rehabilitation and pain management after BTKAs to ensure the best possible outcomes.

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References

1. Barrett J, Baron JA, Losina E, Wright J, Mahomed NN, Katz JN. Bilateral total knee replacement: staging and pulmonary embolism. *J Bone Joint Surg Am*. 2006;88:2146–2151.
2. Basilico FC, Sweeney G, Losina E, Gaydos J, Skonecki D, Wright EA, Katz JN. Risk factors for cardiovascular complications following total joint replacement surgery. *Arthritis Rheum*. 2008;58:1915–1920.
3. Benjamin J, Tucker T, Ballesteros P. Is obesity a contraindication to bilateral total knee arthroplasties under one anesthetic? *Clin Orthop Relat Res*. 2001;392:190–195.
4. Berend KR, Morris MJ, Skeels MD, Lombardi AV Jr, Adams JB. Perioperative complications of simultaneous versus staged unicompartmental knee arthroplasty. *Clin Orthop Relat Res*. 2011;469:168–173.
5. Bottner F, Pavone V, Johnson T, Heitkemper S, Sculco TP. Blood management after bilateral total knee arthroplasty. *Clin Orthop Relat Res*. 2003;410:254–261.
6. Bullock DP, Sporer SM, Shirreffs TG Jr. Comparison of simultaneous bilateral with unilateral total knee arthroplasty in terms of perioperative complications. *J Bone Joint Surg Am*. 2003;85:1981–1986.
7. Carson JL, Grossman BJ, Kleinman S, Tinmouth AT, Marques MB, Fung MK, Holcomb JB, Illoh O, Kaplan LJ, Katz LM, Rao SV, Roback JD, Shander A, Tobian AAR, Weinstein R, Swinton McLaughlin LG, Djulbegovic B; Clinical Transfusion Medicine Committee of the AABB. Red blood cell transfusion: a clinical practice guideline from the AABB. *Ann Intern Med*. 2012;157:49–58.
8. Ersozlu S, Akkaya T, Ozgur AF, Sahin O, Senturk I, Tandogan R. Bilateral staged total knee arthroplasty in obese patients. *Arch Orthop Trauma Surg*. 2008;128:143–148.
9. Fabi DW, Mohan V, Goldstein WM, Dunn JH, Murphy BP. Unilateral vs bilateral total knee arthroplasty risk factors increasing morbidity. *J Arthroplasty*. 2011;26:668–673.
10. Ferraris VA, Davenport DL, Saha SP, Austin PC, Zwischenberger JB. Surgical outcomes and transfusion of minimal amounts of blood in the operating room. *Arch Surg*. 2012;147:49–55.
11. Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof E, Fleischmann KE, Freeman WK, Froehlich JB, Kasper EK, Kersten JR, Riegel B, Robb JF, Smith SC Jr, Jacobs AK, Adams CD, Anderson JL, Antman EM, Buller CE, Creager MA, Ettinger SM, Faxon DP, Fuster V, Halperin JL, Hiratzka LF, Hunt SA, Lytle BW, Nishimura R, Ornato JP, Page RL, Tarkington LG, Yancy CW; American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery); American Society of Echocardiography; American Society of Nuclear Cardiology;

- Heart Rhythm Society; Society of Cardiovascular Anesthesiologists; Society for Cardiovascular Angiography and Interventions; Society for Vascular Medicine and Biology; Society for Vascular Surgery. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery): developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. *Circulation*. 2007;116:e418–499.
12. Forster MC, Bauze AJ, Bailie AG, Falworth MS, Oakeshott RD. A retrospective comparative study of bilateral total knee replacement staged at a one-week interval. *J Bone Joint Surg Br*. 2006;88:1006–1010.
 13. Hashmi FR, Barlas K, Mann CF, Howell FR. Staged bilateral hip or knee arthroplasties. *J Orthop Surg (Hong Kong)*. 2007;15:159–162.
 14. Hu J, Liu Y, Lv Z, Li X, Qin X, Fan W. Mortality and morbidity associated with simultaneous bilateral or staged bilateral total knee arthroplasty: a meta-analysis. *Arch Orthop Trauma Surg*. 2011;131:1291–1298.
 15. Hutchinson JR, Parish EN, Cross MJ. A comparison of bilateral uncemented total knee arthroplasty: simultaneous or staged? *J Bone Joint Surg Br*. 2006;88:40–43.
 16. Jankiewicz JJ, Sculco TP, Ranawat CS, Behr C, Tarrentino S. One-stage versus 2-stage bilateral total knee arthroplasty. *Clin Orthop Relat Res*. 1994;309:94–101.
 17. Jules-Elysee KM, Wilfred SE, Memtsoudis SG, Kim DH, YaDeau JT, Urban MK, Lichardi ML, McLawhorn AS, Sculco TP. Steroid modulation of cytokine release and desmosine levels in bilateral total knee replacement: a prospective randomized controlled trial. *J Bone Joint Surg Am*. 2012;94:2120–2127.
 18. Jules-Elysee KM, YaDeau JT, Urban MK. Pulmonary artery versus central venous catheter monitoring in the outcome of patients undergoing bilateral total knee replacement. *HSS J*. 2009;5:27–30.
 19. Kim S, Losina E, Solomon DH, Wright J, Katz JN. Effectiveness of clinical pathways for total knee and total hip arthroplasty: literature review. *J Arthroplasty*. 2003;18:69–74.
 20. Kim YH, Choi YW, Kim JS. Simultaneous bilateral sequential total knee replacement is as safe as unilateral total knee replacement. *J Bone Joint Surg Br*. 2009;91:64–68.
 21. Lee TH, Marcantonio ER, Mangione CM, Thomas EJ, Polanczyk CA, Cook EF, Sugarbaker DJ, Donaldson MC, Poss R, Ho KK, Ludwig LE, Pedan A, Goldman L. Derivation and prospective validation of a simple index for prediction of cardiac risk of major noncardiac surgery. *Circulation*. 1999;100:1043–1049.
 22. Leitch KK, Dalgorf D, Borkhoff CM, Kreder HJ. Bilateral total knee arthroplasty: staged or simultaneous? Ontario's orthopedic surgeons reply. *Can J Surg*. 2005;48:273–276.
 23. Linstone HA, Turoff M, eds. *The Delphi Method: Technique and Application*. Boston, MA: Addison-Wesley; 1975.
 24. Macfarlane AJ, Prasad GA, Chan VW, Brull R. Does regional anesthesia improve outcome after total knee arthroplasty? *Clin Orthop Relat Res*. 2009;467:2379–2402.
 25. MacGillivray RG, Tarabichi SB, Hawari MF, Raoof NT. Tranexamic acid to reduce blood loss after bilateral total knee arthroplasty: a prospective, randomized double blind study. *J Arthroplasty*. 2011;26:24–28.
 26. Mantilla CB, Horlocker TT, Schroeder DR, Berry DJ, Brown DL. Frequency of myocardial infarction, pulmonary embolism, deep venous thrombosis, and death following primary hip or knee arthroplasty. *Anesthesiology*. 2002;96:1140–1146.
 27. Meehan JP, Danielsen B, Tancredi DJ, Kim S, Jamali AA, White RH. A population-based comparison of the incidence of adverse outcomes after simultaneous-bilateral and staged-bilateral total knee arthroplasty. *J Bone Joint Surg Am*. 2011;93:2203–2213.
 28. 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;467:1568–1576.
 29. 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;466:2617–2627.
 30. Memtsoudis SG, Ma Y, Chiu YL, Poultides L, Gonzalez Della Valle A, Mazumdar M. Bilateral total knee arthroplasty: risk factors for major morbidity and mortality. *Anesth Analg*. 2011;113:784–790.
 31. Memtsoudis SG, Ma Y, Gonzalez Della Valle A, Mazumdar M, Gaber-Baylis LK, MacKenzie CR, Sculco TP. Perioperative outcomes after unilateral and bilateral total knee arthroplasty. *Anesthesiology*. 2009;111:1206–1216.
 32. Memtsoudis SG, Mantilla CB, Parvizi J, Stundner O, Mazumdar M. Have bilateral total knee arthroplasties become safer? A population-based trend analysis. *Clin Orthop Relat Res*. 2013;471:17–25.
 33. Noble J, Goodall JR, Noble DJ. Simultaneous bilateral total knee replacement: a persistent controversy. *Knee*. 2009;16:420–426.
 34. Oakes DA, Hanssen AD. Bilateral total knee replacement using the same anesthetic is not justified by assessment of the risks. *Clin Orthop Relat Res*. 2004;428:87–91.
 35. Parvizi J, Chaudhry S, Rasouli MR, Pulido L, Joshi A, Herman JH, Rothman RH. Who needs autologous blood donation in joint replacement? *J Knee Surg*. 2011;24:25–31.
 36. Pavone V, Johnson T, Saulog PS, Sculco TP, Bottner F. Perioperative morbidity in bilateral one-stage total knee replacements. *Clin Orthop Relat Res*. 2004;421:155–161.
 37. Peskun C, Mayne I, Malempati H, Kosashvili Y, Gross A, Backstein D. Cardiovascular disease predicts complications following bilateral total knee arthroplasty under a single anesthetic. *Knee*. 2012;19:580–584.
 38. Reidy CM, Beach ML, Gallagher JD, Sites BD. Postoperative hemodynamic instability after simultaneous bilateral total knee arthroplasty. *J Patient Saf*. 2010;6:233–237.
 39. Restrepo C, Parvizi J, Dietrich T, Einhorn TA. Safety of simultaneous bilateral total knee arthroplasty: a meta-analysis. *J Bone Joint Surg Am*. 2007;89:1220–1226.
 40. Ritter M, Mamlin LA, Melfi CA, Katz BP, Freund DA, Arthur DS. Outcome implications for the timing of bilateral total knee arthroplasties. *Clin Orthop Relat Res*. 1997;345:99–105.
 41. Ritter MA, Harty LD, Davis KE, Meding JB, Berend M. Simultaneous bilateral, staged bilateral, and unilateral total knee arthroplasty: a survival analysis. *J Bone Joint Surg Am*. 2003;85:1532–1537.
 42. Rojas-Serrano J, González-Velásquez E, Mejía M, Sánchez-Rodríguez A, Carrillo G. Interstitial lung disease related to rheumatoid arthritis: evolution after treatment. *Reumatol Clin*. 2012;8:68–71.
 43. Severson EP, Mariani EM, Bourne MH. Bilateral total knee arthroplasty in patients 70 years and older. *Orthopedics*. 2009;32:316.
 44. Shin YH, Kim MH, Ko JS, Park JA. The safety of simultaneous bilateral versus unilateral total knee arthroplasty: the experience in a Korean hospital. *Singapore Med J*. 2010;51:44–49.
 45. Sliva CD, Callaghan JJ, Goetz DD, Taylor SG. Staggered bilateral total knee arthroplasty performed four to seven days apart

- during a single hospitalization. *J Bone Joint Surg Am.* 2005;87:508–513.
46. Stefánsdóttir A, Lidgren L, Robertsson O. Higher early mortality with simultaneous rather than staged bilateral TKAs: results from the Swedish Knee Arthroplasty Register. *Clin Orthop Relat Res.* 2008;466:3066–3070.
 47. Stundner O, Chiu YL, Sun X, Mazumdar M, Fleischut P, Poultides L, Gerner P, Fritsch G, Memtsoudis SG. Comparative perioperative outcomes associated with neuraxial versus general anesthesia for simultaneous bilateral total knee arthroplasty. *Reg Anesth Pain Med.* 2012;37:638–644.
 48. Taylor BC, Dimitris C, Mowbray JG, Gaines ST, Steensen RN. Perioperative safety of two-team simultaneous bilateral total knee arthroplasty in the obese patient. *J Orthop Surg Res.* 2010;5:38.
 49. Thorey F, Stukenborg-Colsman C, Windhagen H, Wirth CJ. The effect of tourniquet release timing on perioperative blood loss in simultaneous bilateral cemented total knee arthroplasty: a prospective randomized study. *Technol Health Care.* 2008;16:85–92.
 50. Urban MK, Chisholm M, Wukovits B. Are postoperative complications more common with single-stage bilateral (SBTKR) than with unilateral knee arthroplasty: guidelines for patients scheduled for SBTKR. *HSS J.* 2006;2:78–82.
 51. Walmsley P, Murray A, Brenkel IJ. The practice of bilateral, simultaneous total knee replacement in Scotland over the last decade: data from the Scottish Arthroplasty Project. *Knee.* 2006;13:102–105.
 52. Wu CC, Lin CP, Yeh YC, Cheng YJ, Sun WZ, Hou SM. Does different time interval between staggered bilateral total knee arthroplasty affect perioperative outcome? A retrospective study. *J Arthroplasty.* 2008;23:539–542.
 53. Yoon HS, Han CD, Yang IH. Comparison of simultaneous bilateral and staged bilateral total knee arthroplasty in terms of perioperative complications. *J Arthroplasty.* 2010;25:179–185.
 54. Zeni JA Jr, Snyder-Mackler L. Clinical outcomes after simultaneous bilateral total knee arthroplasty: comparison to unilateral total knee arthroplasty and healthy controls. *J Arthroplasty.* 2010;25:541–546.