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Modern abbreviated computer navigation of the femur reduces blood loss in total knee arthroplasty

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ABSTRACT

Computer assisted surgery (CAS) optimizes component position in total knee arthroplasty (TKA), yet effects specifically on blood loss are less known. This study purpose was to determine whether a modern abbreviated CAS protocol would reduce blood loss in TKA compared to conventional instrumentation. One hundred consecutive TKAs were retrospectively reviewed comparing abbreviated CAS versus conventional IM instrumentation. Blood loss was determined using drain output, change in hemoglobin, and calculated blood loss. The CAS group demonstrated less hourly drain output ($P = 0.02$), hemoglobin change ($P = 0.001$), and estimated blood loss ($P = 0.001$) versus conventional instrumentation. With proven advantages of accurate component placement and improved functional outcome after TKA, CAS provides additional value by reducing blood loss in TKA.

Computer assisted surgery (CAS) in total knee arthroplasty (TKA) has been repeatedly shown to reduce outliers in component position [1–5] and improve functional outcomes [6,7], while other reports have shown no benefit over conventional instrumentation [8]. Yet, CAS remains infrequently adopted by most surgeons who perform knee arthroplasty. Some have explored potential perioperative benefits of CAS that may be realized by avoiding the intramedullary canal, such as decreasing the systemic embolic load [9,10] and decreasing blood loss [11–15]. Blood loss after TKA is variable, but not uncommon with up to 1500 mL or a decrease in hemoglobin of 3–4 g/dL after TKA [16,17]. Currently, blood salvage techniques in TKA, such as tranexamic acid, fibrin sealants, and bipolar sealing devices are receiving much attention in order to decrease blood transfusions, which can be costly and contribute to increased risk of infection, fluid overload and increased length-of-stay [18]. However, blood conservation as a benefit of CAS is frequently overlooked and not well described. The purpose of this study is to evaluate whether a modern abbreviated CAS technique is associated with decreased postoperative blood loss following TKA compared to the conventional intramedullary (IM) femoral alignment technique.

Methods

A retrospective, IRB-approved study of a consecutive series of 100 patients who underwent a primary cemented TKR performed between June 2011 and April 2013. Fifty patients underwent TKR using conventional alignment followed by 50 patients using an abbreviated computer navigation protocol. This consecutive grouping was available due to the implementation of CAS in the senior author's practice, which enabled a retrospective evaluation of the consecutive patients prior to CAS implementation to those 50 patients after implementation. Inclusion criteria included patients who underwent a unilateral cemented knee arthroplasty secondary to primary osteoarthritis or inflammatory arthritis. All surgeries were performed with single-dose intrathecal analgesia and light general anesthesia and had identical perioperative protocols. In order to maintain the scientific strength of the study methods and analysis, factors that could affect intraoperative or perioperative blood loss were considered confounding variables, and patients with these variables were excluded. Patients who did not have intrathecal analgesia, had cementless implant fixation, took antiplatelet medications (except aspirin), had clotting disorders, had existing periarticular hardware, or malfunction of the tourniquet during the case were excluded.

All surgeries were performed by a fellowship-trained arthroplasty surgeon. The surgeon was experienced in both conventional and CAS instrumentation. Implants were of one design, but included both posterior cruciate retaining and sacrificing implants. A tourniquet was used from surgical incision until the postoperative compression dressing was applied and tranexamic acid was not used in any case during this study period. Electronic medical records (EMR) were reviewed to obtain all data.

The operations were all performed through a median peri-patellar approach. Conventional extra-medullary alignment guides were used to cut the tibia in all cases and the two study groups differed only in the methodology of enacting the distal femoral cut. In the conventional group, an entry hole in the distal femur was created 1 cm above the posterior cruciate ligament insertion and an IM rod was used for placement of the distal femoral cutting guide. A femoral bone plug was fashioned

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and placed prior to cementation of the implants in order to minimize blood extrusion from the femoral canal postoperatively in all conventional instrumentation cases. In the CAS group, an abbreviated protocol utilized an articulating surface mounted computer CAS system (Stryker Navigation, Kalamazoo, MI), which avoided any pin placement outside of the arthrotomy, to enact the distal femoral cut. After the distal femoral cut, the remaining operation proceeded in standard fashion with conventional instrumentation including an extra-medullary tibial cutting guide. After component cementation, an intra-articular cocktail containing epinephrine, ropivacaine and morphine was injected into the soft tissues around the arthrotomy to facilitate postoperative pain control in both groups. Prior to closure of the arthrotomy, a medium hemovac drain was placed in all knees and removed the morning of postoperative day one. For thromboprophylaxis low dose Coumadin was used with patients given 5 mg orally on the night of surgery and subsequently adjusted daily with an INR goal set at 1.8 to 2.2.

The primary outcome was to determine blood loss after TKR in each group. This was evaluated using four metrics: (1) average hemovac drain output per hour; (2) total hemovac drain output; (3) change in hemoglobin levels; (4) calculated total blood loss. Average hemovac drain output per hour was calculated by recording the total drain output divided by the number of hours the drain was in place from the release of the tourniquet at the procedure conclusion until the last recorded volume at the associated time point of that recording. This time point of last drain output recording was used to standardize the data and more accurately the time over which total output was measured, as the drain output was not recorded universally at the time of discontinuation on AM rounds the day following surgery. This was obtained from EMR and the hours were rounded to the nearest 15 minutes and were felt to give a more accurate measure of drain output in order to account for drains that were in place a greater length of time. The change in hemoglobin was calculated by taking the patient's postoperative day 2 hemoglobin level and subtracting it from the preoperative medical clearance appointment hemoglobin level obtained within 30 days of the index procedure. The total blood loss was calculated through an established methodology by taking the estimated blood volume (EBV) and multiplying by (change in hemoglobin)/(average hemoglobin level). This EBV calculation is from the previous work of several authors. The EBV is determined by a formula derived from Nadler, Hidalgo, and Bloch [19], where the EBV is calculated using height, weight, and gender of the patient. Determining the estimated blood loss, or hidden blood loss, is from the work of Gross et al [20], which is based on the relationship of the change in hematocrit (or hemoglobin) and the effects of hemodilution during an operation. It assumes slow/steady blood loss with maintenance of intravascular volume with red cell free fluids. This formula was initially intended for the estimation of intraoperative blood loss, but has been modified by others for estimating perioperative blood loss after TKA [12,21].

All data were recorded in an Excel spreadsheet and statistical analysis using two-sample Student t-test was performed using the Microsoft Excel Statistics Tool (Microsoft Corporation, Redmond, Washington) to determine the *P* value between the conventional and CAS groups with regards to outcome measures. A *P*-value of less than or equal to 0.05 was considered statistically significant. In order to ensure sufficient statistical power with the given sample size, a post-hoc power analysis was performed using the observed changes in hemoglobin levels between the two groups. The effect size was calculated at 0.9 and the power was determined to be 0.86 for a sample size of 48 and considered adequate statistical power.

Results

One hundred patients were involved in this retrospective study. The first 50 patients used the intramedullary femoral canal for alignment of the distal femoral cutting guide. The next 50 patients used CAS for alignment of the distal femoral cutting block. Two patients were excluded from the CAS group after data collection; one because the patient was taking plavix and the other due to malfunction of the tourniquet, which was released early during the procedure. The height, weight, BMI, preoperative hemoglobin, tourniquet time, and length of stay were recorded and summarized in Table 1. There was no statistical difference between the two groups with regards to these variables except for tourniquet time. On average the tourniquet time was 11 minutes longer in the CAS group ($P \leq 0.001$) and included procedures where post-graduate education was occurring.

Table 1
Comparison of Preoperative Demographics and Tourniquet Time.

	Conventional	CAS	*P* value
Height (cm)	166.5 (152.4–185.0)	165.2 (182.2–144.8)	0.483
Weight (kg)	93.3 (62.0–146.4)	93.2 (58.6–160)	0.980
Body mass index	33.6 (22.8–47.3)	33.9 (19–49)	0.840
Preop hemoglobin (g/dL)	13.3 (11.2–16.7)	12.3 (11.2–16.4)	0.870
Tourniquet time (min)	70.9 (40–139)	81.9 (58–107)	<0.001
Length of stay (days)	2.5	2.6	0.539

The primary outcome measures all showed decreased blood loss with the use of computer navigation. The mean *total drain output* of 512.6 mL (range, 160–925 mL) in the CAS group was less than the 643.3 mL (range, 250–1240 mL) in the conventional instrumentation group ($P = 0.004$). The average drain output *per hour* was less in the CAS group at 33.8 mL/hour (range, 9.1–81.1 mL/hour) compared to 40.5 mL (range, 12.7–75.2 mL/hour) in the conventional group ($P = 0.02$). The average change in hemoglobin was only 2.2 g/dL (range, 0.2–4.9 mL) in the CAS group compared to 3.1 g/dL (range, 0.4–4.9 mL) in the conventional group ($P = 0.001$). Finally, total calculated blood loss was less in the CAS group at 925 mL (range, 64–2036 mL) compared to 1327 mL (range, 139–2244 mL) in the conventional group ($P = 0.001$). The primary outcome measurements and *P*-values are summarized in Table 2. No patients in either group required a blood transfusion postoperatively.

In order to account for any confounding variability that may have occurred due to the heterogeneity of implant design (PS vs. CR) within each group, we performed the statistical analysis with the 12 PS designs removed from the conventional group and the 3 PS designs removed from the CAS group. In this analysis, the mean *total drain output* of 499.7 mL in the CAS group was less than the 627.9 mL in the conventional instrumentation group ($P = 0.01$). The average drain output *per hour* was less in the CAS group at 33.2 mL/hour compared to 39.3 mL in the conventional group ($P = 0.06$). The average change in hemoglobin was 2.2 g/dL in the CAS group compared to 3.0 g/dL in the conventional group ($P = 0.0004$). Finally, total calculated blood loss was less in the CAS group at 930 mL compared to 1295 mL in the conventional group ($P = 0.001$).

Discussion

Recent studies evaluating blood loss after TKA with and without the use of computer navigation have been conflicting. Several studies have shown decreased blood loss with CAS [11–15], while others have not demonstrated any significant benefit [22–24]. In this study with exclusion of confounding variables, our findings showed a consistent reduction in blood loss when CAS was employed in all primary outcome measurements. The hemovac drain output per hour is a novel approach to measuring blood loss following TKA with intent for improved accuracy and was developed to avoid inconsistencies associated with most "drain output" reports which fail to account for the actual time the drain was in place. The CAS group had 6.7 mL/hour less blood on average than the conventional alignment. This can be reasoned to be a more accurate method to compare blood loss between groups since hemovac drain output is time dependent. Using the more commonly reported total hemovac drain output, our findings demonstrated 130 mL less hemovac drain output in the CAS group (CAS, 513 mL; conventional,