The Effect of Implementation of Preoperative and Postoperative Care Elements of a Perioperative Surgical Home Model on Outcomes in Patients Undergoing Hip Arthroplasty or Knee Arthroplasty

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BACKGROUND: The Perioperative Surgical Home (PSH) seeks to remedy the currently highly fragmented and expensive perioperative care in the United States. The 2 specific aims of this health services research study were to assess the association between the preoperative and postoperative elements of an initial PSH model and a set of (1) clinical, quality, and patient safety outcomes and (2) operational and financial outcomes, in patients undergoing total hip arthroplasty (THA) or total knee arthroplasty (TKA).

METHODS: A 2-group before-and-after study design, with a nonrandomized preintervention PSH (PRE-PSH group, N = 1225) and postintervention PSH (POST-PSH group, N = 1363) data-collection strategy, was applied in this retrospective observational study. The 2 study groups were derived from 2 sequential 24-month time periods. Conventional inferential statistical tests were applied to assess group differences and associations, including regression modeling.

RESULTS: Compared with the PRE-PSH group, there was a 7.2% (95% confidence interval [CI] 4.0%–10.4%, $P < .001$) increase in day of surgery on-time starts (adjusted odds ratio [aOR] 2.54; 95% CI 1.70–3.80; $P < .001$); a 5.8% (95% CI 3.1%–8.5%, $P < .001$) decrease in day of surgery anesthesia-related delays (aOR 0.66; 95% CI 0.52–0.84, $P < .001$); and a 2.2% (95% CI 0.5%–3.9%, $P = .011$) decrease in ICU admission rate (aOR 0.45; 95% CI 0.31–0.66, $P < .001$) in the POST-PSH group. There was a 0.6 (95% CI 0.5–0.7) decrease in the number of ICU days in the POST-PSH group compared with the PRE-PSH group ($P = .028$); however, there was no significant difference (0.1 day; 95% CI −0.03 to 0.23) in the total hospital length of stay between the 2 study groups ($P = .14$). There was also no significant difference (1.2%; 95% CI −0.6 to 3.0) in the all-cause readmission rate between the study groups ($P = .18$). Compared with the PRE-PSH group, the entire POST-PSH group was associated with a $432 (95% CI 270–594) decrease in direct nonsurgery costs for the THA ($P < .001$) and a $601 (95% CI 430–772) decrease in direct nonsurgery costs for the TKA ($P < .001$) patients.

CONCLUSIONS: On the basis of our preliminary findings, it appears that a PSH model with its expanded role of the anesthesiologist as the "perioperativist" can be associated with improvements in the operational outcomes of increased on-time surgery starts and reduced anesthesia-related delays and day-of-surgery case cancellations, and decreased selected costs in patients undergoing THA and TKA. (Anesth Analg 2016;XXX:00–00)

The Perioperative Surgical Home (PSH) is a paradigm shift that seeks to remedy the currently highly fragmented and expensive perioperative care in the United States.[1,2] The PSH is a patient-centered approach to the surgical patient, with a strong emphasis on process standardization, evidence-based clinical care pathways, as well as robust coordination and integration of care. This new model of care guides the patient and their family members through the complexities of the perioperative continuum, especially during transitions of care, from the decision for surgery to the postdischarge phase.[3] As this new patient care model continues to be defined and implemented, there will likely be variants of the PSH, predicated on the local infrastructure, resources, internal/external forces, and the degree of collaboration among all of its institutional stakeholders.[1,4]

Furthermore, a successful PSH model will not be a static entity but will undergo continuous development, with an attendant expansion of scope and services. For example, at the University of Alabama at Birmingham (UAB), when we initiated our PSH model in October 2010, we initially focused on the preoperative phase of care. In October 2012, our PSH model was expanded to include the postoperative phase of care. This initial PSH model at UAB was predicated on an expanded role of the anesthesiologist as the "perioperativist."[3]

Clinical proof-of-concept has been defined as "[the] construction of working prototypes of the necessary functionality and infrastructure in sufficient quality to investigate evidence for improving health in daily use for a suitable period of time; a limited but relevant set of people [patients] serving as [study] subjects."[5] An initial, limited scale clinical

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proof-of-concept study could be undertaken appropriately at one's institutional level to determine the operational and fiscal viability of further development and deployment ("Go-No Go decision") of a novel yet nascent PSH model for the management of surgical patients.[4]

The 2 specific aims of this clinical proof-of-concept, health services research study were thus to assess the association between the dissemination and implementation of the preoperative and postoperative elements of the initial UAB PSH model and a subset of (1) clinical, quality, and patient safety outcomes; and (2) operational and financial outcomes, in patients undergoing total hip arthroplasty (THA) or total knee arthroplasty (TKA).

METHODS

This study was approved by the UAB institutional review board (IRB) (X141001007). This study was granted expedited status by the UAB IRB because the research involved materials (data, documents, records) collected solely for nonresearch purposes (such as medical treatment or diagnosis) and the research used quality assurance methodologies. This study per se also involved minimal additional risk to the study participants. A waiver of informed consent documentation and a waiver of authorization also were granted by the UAB IRB. This study was a retrospective, observational (before-and-after) care redesign study. It was not a prospective clinical trial. Thus, it was not registered.

Study Design

A 2-group before-and-after study design, with a nonrandomized, preintervention, and postintervention data collection strategy, was applied in this retrospective observational study.[6,7] This work thus adheres to the STROBE (Strengthening the Reporting of Observational studies in Epidemiology) reporting guidelines and associated checklist.[8,9]

Study Participants and Study Groups

Patients 19 years of age or older who underwent either a THA or a TKA at UAB Highlands Hospital, our 219-bed satellite facility and PSH venue, were eligible for inclusion in this study. The orthopedic joint surgery outpatient clinics also were located on the UAB Highlands Hospital campus.

Patients in the preintervention PSH (PRE-PSH) group and postintervention PSH (POST-PSH) group were identified by the use of our institutional claims database as those patients who were billed with a Current Procedural Terminology code for a THA or a TKA (Supplemental Digital Content, Appendix A, http://links.lww.com/AA/B576). This institutional claims database included every such patient who underwent a THA or TKA. During the 24-month PRE-PSH and 24-month POST-PSH epochs, there were no changes in the involved orthopedic surgeons and in their surgical techniques.

The 2 study groups were derived from 2 sequential 24-month time periods. To reduce selection bias, the PRE-PSH group consisted of all consecutive THA and TKA patients who underwent surgery in the 24-month period from October 1, 2008, to September 30, 2010. During this 24-month PRE-PSH epoch, patients were seen in a longstanding preadmission testing clinic, at which time a registered nurse essentially collected basic clinical information (history of present illness, review of systems, and anesthesia history), and widely variable laboratory tests, electrocardiogram, and chest radiographs were ordered. Patients with specific symptoms had additional diagnostic tests (eg, resting transthoracic echocardiogram) ordered, after discussion with an attending anesthesiologists working in the operating room that day. This preadmission testing clinic functioned as a simple preoperative screening clinic. During this 24-month PRE-PSH epoch, postoperative patient comanagement in the intensive care unit (ICU) and on the routine inpatient unit was provided by a group of hospital-employed and private practice internal medicine hospitalists, with intensivist consultation available on request.

The dissemination and implementation of our PSH occurred in 2 sequential phases. Study data were collected only during the second phase, which represented our full PSH model. During the 24-month period from October 1, 2010, to September 30, 2012, phase 1 of our PSH model was fully operational. The principal element of phase 1 was a preoperative assessment, consultation, and treatment (PACT) clinic, with its widely expanded scope of services and new staffing model (Figure 1). This expansion included an onsite attending anesthesiologist working in collaboration with a team of nurse practitioners. A series of laboratory testing, electrocardiogram, cardiac risk-stratification and testing, and preoperative medication protocols were implemented. A pharmacist-based preoperative medication reconciliation program and a regional analgesia patient education/consent process were also implemented in the PACT clinic. During phase 1 of our PSH model, postoperative patient comanagement in the ICU and on the routine inpatient units was still provided primarily by the group of internal medicine hospitalists.

During the subsequent 24-month period from January 1, 2013, to December 31, 2014, phase 2 of our PSH model was fully operational. The additional principal element of phase 2 was an anesthesia-intensivist and a cadre of nurse practitioners (ie, an "anesthesia-intensivist care team") caring for surgical patients postoperatively while they were both in the ICU and on the routine inpatient unit (Figure 1). This anesthesia-intensivist care team cared for these patients on a continuous basis (24-hour a day coverage with daily rounds) while they were in the hospital. This new postoperative care service was initiated (piloted) on October 1, 2012, but was not fully operational until January 1, 2013. The participation of this anesthesia-intensivist care team (patient comanagement) occurred via an order ("consult") placed in the postanesthesia care unit (PACU) by the orthopedic surgical service. This consult order was placed solely at the discretion of the orthopedic surgical service.

To reduce selection bias, the enrolled and analyzed POST-PSH group consisted of all consecutive patients undergoing THA or TKA who underwent surgery during the 24-month period from January 1, 2013, to December 31, 2014. All of the POST-PSH group patients were evaluated by our PACT clinic. A subset of the POST-PSH group patients was cared for postoperatively by our anesthesia-intensivist care team.

To confirm that the POST-PSH-phase 1 and POST-PSH-phase 2 patients had received the aforementioned 2 primary elements of our PSH model care, we determined (a) using

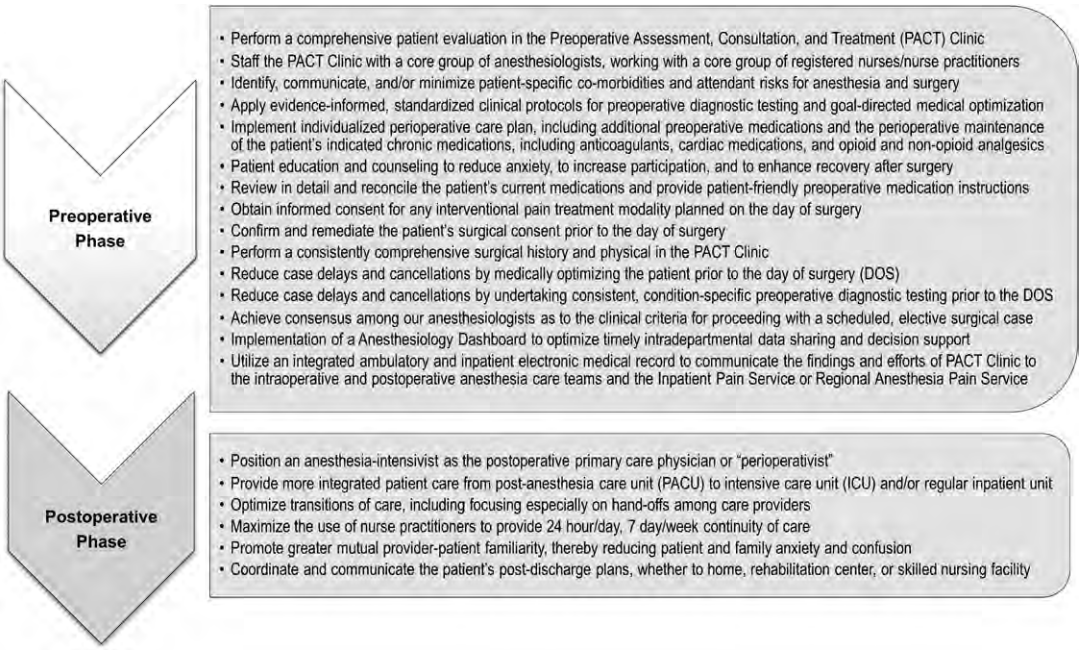

Figure 1. The key additional preoperative and postoperative elements of the Perioperative Surgical Home model at the University of Alabama at Birmingham.

our scheduling database whether a patient had an associated preoperative encounter in our PACT Clinic and (b) using our administrative claims database whether a patient was billed for postoperative care by an anesthesia-intensivist.

There was no standardized anesthesia technique for THR and TKR throughout the entire 6-year study time period. There was an active regional anesthesia pain service throughout the entire study time period; however, no major changes were made in the analgesic regimens or techniques used between the 2 study groups. Likewise, postoperative mobilization and physical therapy were unchanged. Throughout the entire 6-year study time period, there were no major changes in surgical technique (eg, anterior versus posterior approach for a THA and use of tranexamic acid to reduce surgical bleeding).

We did not implement a preoperative anemia management program as a component of our PSH model. As part of an institutional initiative to reduce blood product utilization, however, an intraoperative and postoperative restrictive red blood cell transfusion trigger of <8 g/dL in hospitalized, stable patients[10] was recommended for patients in the entire POST-PSH Group. In stable patients, the recommended practice was also transfusing 1 unit of red blood cells and then clinically reevaluating.

Study Variables

Basic demographic and clinical variables were collected on all study patients. The patient's American Society of Anesthesiologists Physical Status Classification System score (ASA PS score) was assigned immediately before surgery by the assigned attending anesthesiologist. On the basis of conventional clinical risk stratification and to allow for easier clinical interpretation of the data, we elected to collapse the collected patients' ASA PS scores into the dichotomous categories of low score (raw ASA PS scores of 1 or 2) and moderate/high score (raw ASA PS scores of 3 or 4). We were unable to extract from our study subjects' electronic medical records the consistently valid patient-specific (granular) clinical data needed to generate a more robust Charlson Comorbidity Score.[11]

To evaluate the 2 specific aims of this study, a series of clinical, quality, safety, operational, and financial outcome variables (Supplemental Digital Content, Appendix B, http://links.lww.com/AA/B577) were extracted for all PRE-PSH and POST-PSH patients from their initial, acute postoperative hospitalization. Study data were extracted from our institutional electronic scheduling and claims database (GE Centricity Business, GE Healthcare, Wauwatosa, WI); electronic health record repository (PowerInsight, Cerner Corp., Kansas City, MO); and financial administrative database (McKesson Performance Analytics, McKesson Corp., San Francisco, CA). The cost data represented the gross billing charges by the hospital. The cost data did not include the professional fees of the surgeon, anesthesiologist, or hospitalist. All of the extracted cost data were adjusted to December 2014 US dollars using the federally published consumer price index for medical care.[a] Complete data were successfully extracted for all the study variables on 100% of the currently enrolled patients.

Statistical Analysis

Continuous variables were reported as a mean and standard deviation (SD), or if the data were skewed, as a median and interquartile range (IQR). Continuous data were assessed for normality with a Shapiro-Wilk test and by examining Q-Q plots, and if non-normally distributed, they were analyzed as such. Normally distributed data were compared between groups via a *t*-test with nonequal variances. Non-normally

[a]US Department of Labor, Bureau of Labor Statistics. Databases, Tables and Calculators by Subject. Available at: http://data.bls.gov/timeseries/CUUR0000SAM?output_view=pct_12mths. Accessed June 2, 2015.

distributed data were compared via a Mann-Whitney *U* test. Categorical variables were reported with frequency counts and percentages. Categorical data were compared between groups with a χ^2 test or Fisher exact test with cell sizes less <5. Absolute standardized difference scores have been recommended for comparing baseline covariates in clinical trials as well as with nonrandomized, observational study data to reduce the potential for a practically insignificant difference achieving statistical significance solely based on a large sample size.[12,13] An absolute standardized difference score also was thus calculated for all study group baseline covariates.

We also used a series of binary logistic regression models to assess the association between the individual dichotomous-dependent outcome variables (day of surgery on-time start, day of surgery anesthesia-related delay, ICU admission, 30-day readmission) and the study group assignment, controlling for the potential confounding effect of the significant independent covariates of sex (female/male); type of surgery (THA or TKA); ASA PS score (1/2 or 3/4); and surgeon ("A, B, or C"). Age and race were considered but not included in the final models because they did not demonstrate significance in the intergroup bivariate analyses (Table 1). The logistic regression models used a forced entry method. All variables significant in initial bivariate analysis at $P < .05$ were forced into the models.

Table 1. Demographic and Clinical Characteristics of the Study Participants

Variable	PRE-PSH (A) N = 1225	POST-PSH (B) N = 1363	A vs B *P*	Absolute Standardized Difference score
Age, mean ± SD	60.8 ± 13.7	61.7 ± 12.9	.061	0.07
Sex, n (%)			.037	0.08
Female	747 (61)	776 (57)		
Male	478 (39)	587 (43)		
Race, n (%)			.144	0.09
Caucasian	814 (66)	949 (70)		
African American	399 (33)	394 (29)		
Other	12 (<1)	20 (1)		
Surgery type, n (%)			.048	0.08
Total hip arthroplasty	577 (47)	695 (51)		
Total knee arthroplasty	648 (53)	668 (49)		
Surgery type, n (%)				
Primary arthroplasty	928 (76)	984 (72)	.040	0.09
Revision arthroplasty	297 (24)	379 (28)		
ASA classification, n (%)			<.001	0.27
I	7 (<1)	8 (<1)		
II	404 (33)	270 (20)		
III	803 (66)	1071 (78)		
IV	11 (<1)	14 (1)		
V	0 (0)	0 (0)		
Surgeon, n (%)			<.001	0.33
A	459 (38)	731 (54)		
B	398 (33)	379 (28)		
C	330 (27)	168 (12)		
Other	38 (3)	84 (6)		

Abbreviations: ASA, American Society of Anesthesiologists; POST, post; PRE, pre; PSH, Perioperative Surgical Home; SD, standard deviation.

We used a multivariable linear regression model to assess the differences between the individual continuous dependent outcome variables (hospital length of stay and ICU days) and the study group assignment, controlling for the potential confounding effect of the significant independent covariates of sex (female/male); type of surgery (THA or TKA); ASA PS score (1/2 or 3/4); and surgeon ("A, B, or C"). We also calculated multivariable associations for financial data for the patients undergoing THA or TKA, controlling for ASA PS score and surgeon. These linear regression models used a forced entry method. All variables significant in initial bivariate analysis at $P < .05$ were forced into the models.

Given the relatively short, immediate perioperative data collection period (date of surgery to 30 days postoperatively), loss to follow-up was not considered. Three ICU patient subgroups were analyzed (Table 3), but no variable interactions were analyzed. No sensitivity analyses were performed. No a priori sample size determination and power analysis were performed. The study sample sizes instead were based on the programmatic 24-month preintervention and postintervention time periods. Our resulting sample sizes had 90% power to detect a 5.4% difference in day of surgery on-time start rate and a $280 difference (with an assumed SD of $2137) in direct, nonsurgical cost, both with an alpha of 0.05. For all statistical analyses, a *P*-value of <.05 was considered significant. Statistical analyses were performed using SAS, Version 9.3 (SAS Institute Inc., Cary, NC).

RESULTS

Patients were stratified by the time period during which they received their perioperative care, as described previously. A total of 1225 THA/TKA patients were identified and included in the PRE-PSH group. A total of 1363 THA/TKA patients were identified and included in POST-PSH group. Of these 1363 POST-PSH patients, 420 patients were evaluated preoperatively in our PACT clinic and received postoperative care from our anesthesia-intensivist care team (Figure 2).

There were no significant differences in age ($P = .061$) or racial composition ($P = .14$) between the study groups. There were significant differences between the study groups

Table 3. Logistic Regression Models of the Operational Data for the Study Participants

Study variables	POST-PSH Group (N = 1363) vs PRE-PSH Group (N = 1225) aOR (95% CI)	*P*
Day of surgery on-time start	2.54 (1.70–3.80)	<.001
Day of surgery anesthesia-related delay	0.66 (0.52–0.84)	<.001
Overall ICU admission	0.45 (0.31–0.66)	<.001
PACU to ICU admission	4.57 (2.01–10.36)	<.001
Routine inpatient unit to ICU admission	0.27 (0.12– 0.58)	<.001
ICU readmission (bounce-back)	0.75 (0.17–3.33)	.71
30-day readmission		
All cause	1.08 (0.76–1.54)	.59
Cause-related to surgery procedure	0.81 (0.54–1.21)	.30

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; ICU, intensive care unit; PACU, postanesthesia care unit; POST, postintervention; PRE, preintervention; PSH, perioperative surgical home.

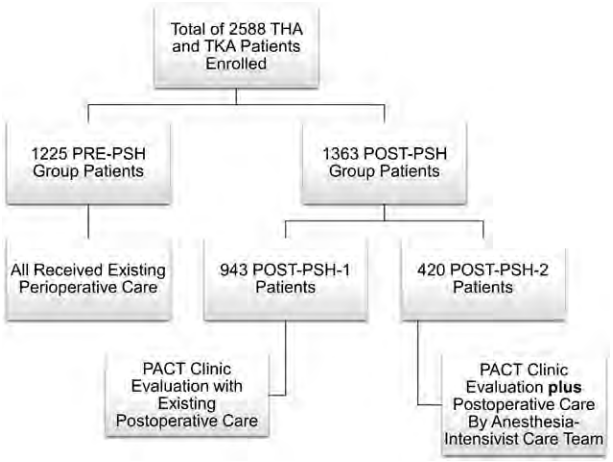

Figure 2. Enrollment process and flow diagram for this retrospective observational study.

in sex proportion (P = .037), proportion of THA patients versus TKA patients (P = .048), and proportion primary arthroplasty patients versus revision arthroplasty patients (P = .040); however, all with an absolute standardized difference score of <.10. There was a significant difference between the study groups in ASA PS scores (P < .001) with an absolute standardized difference score of 0.30. There was a significant difference in the distribution of surgical cases among the participating surgeons (P < .001) (Table 1).

Clinical, Quality, and Patient Safety Outcomes

Bivariate (Unadjusted) Analyses

The observed mortality rate was 0% in the PRE-PSH group and POST-PSH group. There were only 2 observed significant group differences in the clinical, quality, and patient safety outcome variables (as listed in Appendix B, http://links.lww.com/AA/B577). Specifically, 12% (95% confidence interval [CI] 9.6%–14.4%) more patients in the POST-PSH group versus PRE-PSH group received blood clot preventive therapy 24 hours before and 24 hours after surgery (P < .001). A total of 325 (26.5%) patients in the PRE-PSH group versus 219 (16.1%) patients in the entire POST-PSH group received a red blood cell transfusion during their initial surgical hospitalization (P < .001). This observed 10.4% (95% CI 7.3%–13.5%) difference blood transfusion rate equated to a crude odds ratio of 0.53 (95% CI 0.43–0.64; P < .001). The patients transfused in PRE-PSH group received marginally significantly more units of red blood cells (median of 2, IQR 1–3) than the patients transfused in the POST-PSH group (median of 2, IQR 1–2) (P = .047).

Operational Outcomes

Bivariate (Unadjusted) Analyses

When compared with the PRE-PSH Group, the POST-PSH group was associated with a 7.2% (95% CI 4.0%–10.4%) increase in day of surgery on-time starts (P < .001), a 5.8% (95% CI 3.1%–8.5%) decrease in day of surgery anesthesia-related delays (P < .001), and a 2.2% (95% CI 0.5%–3.9%) decrease in ICU admission rate (P = .011) (Table 2).

The observed same-day cancellation rate was 19.4% (295 of 1420 total scheduled THA and TKA cases) in the PRE-PSH time period versus 14.4% in the POST-PSH time period (229 of 1592 total scheduled THA and TKA cases) (P < .001). This observed 5.0% (95% CI 2.4%–7.6%) difference in the same-day cancellation rate equated to a crude odds ratio of 0.70 (95% CI 0.57, 084; P < .001). No adjustment for ASA PS scores was performed because these scores were not assigned routinely by the attending anesthesiologist on the day or surgery for patients cancelled on the day of surgery.

Further analysis of the ICU admissions revealed a 0.6 (95% CI 0.5–0.7) decrease in the number of ICU days in the POST-PSH group compared with the PRE-PSH group (P = .028) (Table 2). A significantly greater proportion (33.3%, 95% CI 16.9%–49.7%) of patients in the POST-PSH group were admitted directly from the PACU to the ICU (P < .001), whereas a significantly greater proportion (30.8%, 95% CI 13.9%–47.7%) of patients in the PRE-PSH group were admitted first from the PACU to a routine inpatient unit, and then to the ICU (P < .001) (Table 2).

There was no significant difference (0.1 day; 95% CI −0.03 to 0.23) in the total hospital LOS between the 2 study groups (P = .14). There was also no significant difference (1.2%; 95% CI −0.6 to 3.0) in the all-cause readmission rate between the study groups (P = .18).

Multivariate (Adjusted) Analyses

Two of these bivariate operational differences were further analyzed with multivariable regression models. After considering the potential confounding effect of the significant independent covariates of sex (female/male), type of surgery (THA or TKA, and primary or revision), ASA PS score (1/2 or 3/4), and surgeon (A, B, or C), we found an associated increase (β-coefficient) of 0.04 (95% CI −0.09 to 0.18) day in the hospital length of stay (P = .54). After considering the potential confounding effect of the significant independent covariates of sex (female/male), type of surgery (THA or TKA), and ASA PS score (1/2 or 3/4), there was an associated decrease (β-coefficient) of 0.6 (95% CI −1.1 to −0.04) day in ICU days (P = .036).

The remaining bivariate operational differences were further analyzed with logistic regression models that controlled for the significant independent covariates of sex, type of surgery, ASA PS score, and surgeon. The resulting adjusted odds ratios are reported in Table 3.

The outcome variable of day of surgery on-time start rate was also plotted over time for the Pre-PSH group and the Post-PSH group, with temporal trend lines (Figure 3). These trend lines demonstrated an apparent qualitative difference between the 2 groups.

Financial Outcomes

Multivariate (Adjusted) Analyses

Because the 2 phases of our PSH model at UAB involved mainly the preoperative and postoperative elements of care, we focused primarily on the direct nonsurgery cost, which excluded the costs associated with intraoperative and PACU care. Compared with the PRE-PSH group, the entire POST-PSH group was associated with a $432 (95% CI 270–594) decrease in direct nonsurgery costs for the THA (P < .001) and a $601 (95% CI 430–772) decrease in direct nonsurgery costs for the patients undergoing TKA (P < .001) (Table 4). These decreased direct nonsurgery costs

Table 2. Unadjusted Associations Between Pre-PSH and Post-PSH Patients and Operational Variables

PRE-PSH (A)	POST-PSH (B)	A vs B	
	N = 1225	N = 1363	*P*
Study variable			
Day of surgery on-time starts, n (%; 95% CI)	908 (74.1; 71.6–76.6)	1108 (81.3; 79.2–83.2)	<0.001
Day of surgery anesthesia-related delays, n (%; 95% CI)	206 (16.8; 14.7–18.9)	150 (11.0; 9.3–12.7)	<.001
Observed hospital length of stay, mean days ± SD	3.4 ± 1.6	3.5 ± 1.8	.14
Overall ICU admission rate, n (%; 95% CI)	73 (6.0; 4.7–7.3)	52 (3.8; 2.8–4.8)	.011
ICU admission subgroups			
PACU to ICU admission, n (%; 95% CI)	15 (20.5; 18.2–22.8)	28 (53.8; 51.2–56.4)	<.001
Routine inpatient unit to ICU admission, n (%; 95% CI)	52 (71.2; 68.7–73.7)	21 (40.4; 37.8–43.0)	<.001
ICU readmission (bounce-back), n (%; 95% CI)	6 (8.2; 6.7–9.7)	3 (5.8; 4.6–7.0)	.73
ICU days, mean days ± SD	2.4 ± 1.6	1.8 ± 1.3	.028
30-day readmission, n (%; 95% CI)			
All-cause readmission	62 (5.1; 3.9–6.3)	86 (6.3; 5.0–7.6)	.18
Surgery procedure-related cause readmission	51 (4.2; 3.1–5.3)	57 (4.1; 3.0–5.2)	.99

Abbreviations: CI, confidence interval; ICU, intensive care unit; PACU, postanesthesia care unit; POST, postintervention; PRE, preintervention; PSH, Perioperative Surgical Home; SD, standard deviation.

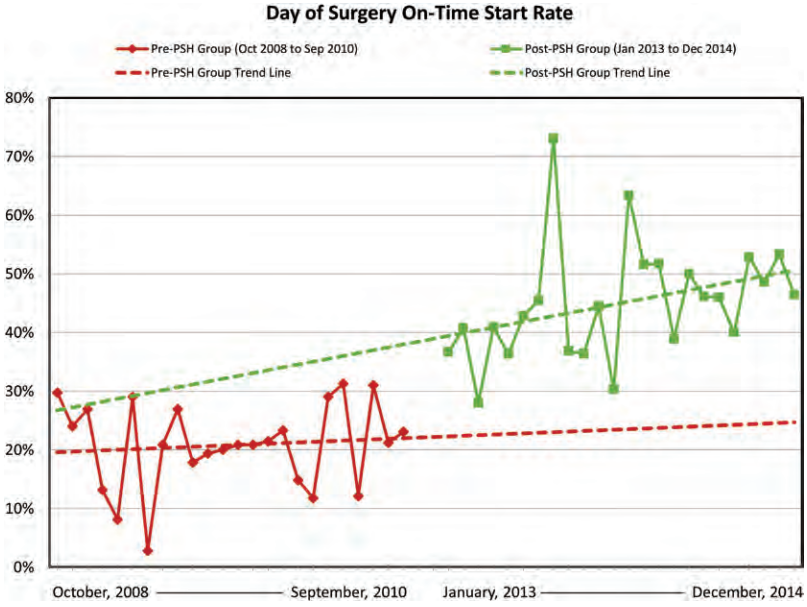

Figure 3. Outcome variable of day of surgery on-time start rate plotted over time for the initial Pre-Perioperative Surgical Home Group and the subsequent Post-Perioperative Surgical Home Group, with temporal trend lines.

Table 4. Financial Data for the Study Participants (All in December 2014 US Dollars)

Study variable	PRE-PSH (A) N = 1225	POST-PSH (B) N = 1363	A vs B *P*
Total direct medical cost, mean ± SD	$12,676 ± $5707	$15,273 ± $7356	<.001
All THA patients, mean ± SD			
Direct surgery cost	$7,520 ± $3386	$9,779 ± $4710	<.001
Direct cost excluding surgery cost	$4,749 ± $2235	$4,317 ± $1933	<.001
All TKA patients, mean ± SD			
Direct surgery cost	$7,970 ± $3588	$11,826 ± $5696	<.001
Direct cost excluding surgery cost	$5,226 ± $2137	$4,625 ± $2291	<.001

Abbreviations: POST, postintervention; PRE, preintervention; PSH, perioperative surgical home; SD, standard deviation; THA, total hip arthroplasty; TKA, total knee arthroplasty.

for patients undergoing THA or TKA included categories that were likely impacted by the PACT clinic and the "anesthesia-intensivist care team" (Table 5).

Nevertheless, compared with the PRE-PSH group, the POST-PSH group was associated with a significantly increased direct surgery costs for the patients undergoing THA ($P < .001$) and TKA ($P < .001$) (Table 4). This difference was largely due to the increased cost of operating room time, surgical equipment, and surgical supplies, including the hip and knee joint implants (Supplemental Digital Content, Appendix C, http://links.lww.com/AA/B578).

DISCUSSION

Our present PSH clinical proof-of-concept study indicates a positive association between the sequential introduction of the preoperative and postoperative elements of the initial UAB PSH model and a subset of (1) clinical, quality, and patient safety outcomes and (2) operational and financial outcomes in patients undergoing THA or TKA. We posit that our initial PSH model and findings at UAB, which focused primarily on the preoperative and postoperative phases of care in a similar population of patients undergoing THA or TKA, complement the efforts and previously reported findings from the University of California Irvine (UCI).

Table 5. Cost Category Changes Between the Pre-PSH and Post-PSH Study Groups

	Total Knee Arthroplasty Patients	Total Hip Arthroplasty Patients
	Pre-PSH Group to Post-PSH Group % Change	Pre-PSH Group to Post-PSH Group % Change
Direct cost category		
Anesthesiology	−24.1	+1.4
Blood bank	−2.4	+2.1
Central supply	+90.7	+95.7
Lab	−64.3	−36.8
Nursing	+21.2	+13.4
Pharmacy	−12.8	−4.2
Radiology	−71.9	−0.8
Respiratory therapy	−93.2	−110.6
Physical therapy	−35.4	−35.0

Abbreviations: POST, postintervention; PRE, preintervention; PSH, perioperative surgical home.

The previous PSH model and data reported by the team at UCI focused primarily on the intraoperative phase of care. The UCI team applied lean methodology to reduce unnecessary variability in the anesthetic and surgical care of THA and TKA patients.[14] In a preliminary feasibility project, they developed, implemented, and assessed a series of clinical care pathways that defined and standardized management for patients undergoing elective primary THA (n = 51) and TKA (n = 95). Their rigorous standardization of care was associated with a number of positive outcomes, including an incidence of major complications of 0%; in-hospital mortality of 0%; perioperative blood transfusion of 6.2%; and 30-day readmission of 0.7%. All Surgical Care Improvements Project measures were met at 100%. The median (IQR) LOS for THA and TKA was 3 (2–3) and 3 (2–3) days, respectively. Approximately, 50% of the enrolled patients were discharged to a location other than their customary residence (70 to skilled nursing facility and 1 to rehabilitation). A parallel financial review of this initial UCI Total Joint Replacement PSH revealed a total per diem cost (mean ± SD) of $9952 ± $1294 for THA and $10,042 ± $1305 for TKA versus a literature-reported benchmark per diem cost of $16,267 for THA and $17,588 for TKA.[15]

Our current findings also confirm those of 2 previous studies demonstrating the advantages of an anesthesiology-based preoperative clinic visit. We sought to build on these earlier findings by incorporating a robust PACT clinic into our UAB PSH model.

At the University of Chicago, in their general operating rooms, 5.3% of patients evaluated in its anesthesia preoperative medicine clinic were cancelled, compared with 13.0% of patients without such a clinic visit ($P < .001$). Cancellations also were more likely to occur among patients with greater ASA PS scores ($P < .001$).[16]

At the Weiner Center for Preoperative Evaluation at Brigham and Women's Hospital, attention was focused on medical problems requiring further information or management. New problems had a far greater probability of delay (10.7% vs 0.6%) or cancellation (6.8% vs 1.8%) than old (existing) problems. Most of the new medical problems required that a new test or consultation be done, whereas most of the old problems required retrieval of information existing from outside clinics or medical centers. The majority of issues identified were cardiac in origin.[17] The experience in our UAB PACT Clinic was very similar.

Patients in our POST-PSH group had significantly greater ASA PS scores and thus greater comorbidity. This likely reflected that with the implementation of the second element of our PSH model—namely, an anesthesia-intensivist staffing of the UAB Highlands Hospital ICU and routine inpatient units—fewer THA and TKA patients with major comorbidity were alternatively scheduled for their planned surgery at the main UAB Hospital, which presumably resulted in less disruption in patient care and surgeons' operating room block time utilization.

The model of physician staffing in the ICU at UAB Highlands changed from a "low intensity" model in the PRE-PSH period, consisting of hospitalists staffing the ICU with intensivist consultation available, to a "high intensity" model in the POST-PSH period, when all patients admitted to the ICU were under the care of an intensivist. The reduction in ICU LOS during the POST-PSH period is consistent with previous studies demonstrating reduced ICU LOS under "high-intensity" ICU physician staffing models.[18] This reduction in overall ICU admissions during the POST-PSH period suggests a positive influence of our PSH model on the overall need for ICU-level care. Our observed lower rate of ICU admission and ICU LOS during the POST-PSH period, however, may have been related to better triage or simply a redesign of the system.

Interestingly, although we observed an overall decrease in ICU admissions, there was a significant increase in the proportion of patients in the ICU who were admitted to the ICU immediately postoperatively—as opposed to initial admission to a routine inpatient unit followed by transfer to the ICU—in our POST-PSH group (53.8%) versus in our PRE-PSH group (20.5%). This finding likely reflected a greater tendency to preemptively admit patients to the ICU after the creation of a specialty ICU service, in a setting such as ours, where the ICU service was integrated fully into the postoperative care continuum. It also may have resulted from the aforementioned greater patient comorbidity in the POST-PSH group compared with the PRE-PSH group. Earlier admission to the ICU also may have contributed to the reduction in ICU LOS, by allowing earlier recognition of problems, with the opportunity for more rapid correction. The presence of an intensivist-led ICU team also was associated with a reduction of readmissions to the ICU during the same hospitalization.

Our present efforts were intended to serve as a clinical proof-of-concept: (a) to confirm the viability of our working PSH prototype, with the necessary functionality and infrastructure and thus (b) to answer a "Go-No Go" decision about further program development and resource investment.[5] Furthermore, our clinical proof-of-concept process emphasized the identification of previously unforeseen challenges and pitfalls unique to our particular environment to save time and resources and to improve efficiency when a more robust, future model is implemented.[4,5]

In the interim since December 2014 (the closing date for our current post-PSH data collection), we have begun developing and implementing a series of Perioperative Risk Optimization and Management Protocols (PROMPTs),[19] each of which targets a specific clinical condition. This effort reflects the continually evolving nature of our PSH model at UAB.

Limitations

Given the pragmatic yet nonrandomized study design that we applied, there was a potential for unrecognized confounding. Although not obvious during our 6-year data collection period, such potential confounders included unrecognized changes in operating room management, performance-based financial incentives/penalties, surgical practice, pain management, and rehabilitation regimens. The risk of the potential confounding effects of these unrecognized practice changes (eg, on on-time starts and reduced anesthesia-related delays) was significantly increased because of the sustained time period between the 2 study groups.

As noted herein, we were unable to extract from our study subjects' electronic medical records, the consistently valid patient-specific (granular) clinical data needed to generate a more robust Charlson Co-Morbidity Score,[11] and to undertake more rigorous propensity score matching.[20] Our use instead of ASA PS scores may not have controlled adequately for the confounding effect of patient comorbidity.

Given the sequential nature of our 2-phase PSH model implementation and our single-blinded (patients only) study design, a Hawthorne effect may have occurred, whereby the involved health care providers may have changed their behavior in response to their performance being monitored. This potential bias was mitigated by the sustained 24-month postintervention period, as well as the lack of any interim outcomes and provider-level performance data analyses and internal reporting.

Because a significant benefit could have been realized as the result of process redesign that improved work flow and shortened throughput, and thus decreased number of involved staff, applying a time-driven activity-based costing[21] would have demonstrated more accurate, perhaps even greater improvements.

Lastly, as reported by Garson et al[14] and Cyriac et al[22] at UCI, as well as Auyong et al[23] at Virginia Mason Medical Center in Seattle, a more robust perioperative total joint replacement care pathway, which included standardized multimodal analgesia and earlier mobilization and physical therapy, likely would have resulted in even more favorable outcomes.

Future Research

Elements of the PSH and similar surgical care coordination models have been studied in the United States and other developed countries.[24] However, despite the ASA and other early adopters advocating the PSH to be the optimal global model of care for surgical patients,[1–3,25–29] there have been only a small number of published studies providing validation of this new model of care.[14,15,30] Therefore, there is a need for additional studies that demonstrate that incorporating the PSH promotes patient-centeredness and optimizes the value of surgical patient care.

More externally valid and hence important information could be obtained by simultaneously developing elements of the PSH at several institutions with different population health—for example, through the ASA-sponsored PSH Learning Collaborative.[31]

For example, an important specific focus of future PSH research should be the posthospital discharge phase of care. Indeed, because of pressure on the hospitals to shorten the length of stay of surgical patients, patients with multiple comorbidities and/or who underwent complex surgery often are transferred to skilled nursing facilities. The cost of these skilled facilities continues to increase every year, with many surgical patients never returning to live at home.[32–34] The cost-effectiveness and cost-utility of care provided by these postsurgical facilities, including hospital readmission and health-related quality of life during the first 30–90 days after hospital discharge, should be evaluated in future PSH studies.

Lastly, this future research will likely involve a strong reiterative, continuous quality improvement component based on process learning and outcome evaluation.[35] This continuous quality improvement can be readily performed by applying Plan-Do-Study-Act cycles or closely related Plan-Do-Check-Act cycles.[35,36]

CONCLUSIONS

On the basis of our preliminary findings, it appears that our initial PSH model at UAB with its expanded role of the anesthesiologist as the "perioperativist"[3] can be associated with improvements in the operational outcomes of increased on-time surgery starts and reduced anesthesia-related delays and decreased selected costs in patients undergoing THA or TKA. Although the day-of-surgery case cancellation rate also significantly decreased after implementing our PSH model, it remained elevated, representing an opportunity for additional process improvement.

These exploratory findings have supported our departmental and institutional "Go" decision to continue to expand the scope of our PSH model. We have begun a series of more focused confirmatory studies, examining the various components of our expanding PSH model. ■

DISCLOSURE

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