Medical and Surgical Comanagement after Elective Hip and Knee Arthroplasty

A Randomized, Controlled Trial

Jeanne M. Huddleston, MD; Kirsten Hall Long, PhD; James M. Naessens, MPH; David Vanness, PhD; Dirk Larson, MS; Robert Trousdale, MD; Matt Plevak, BS; Miguel Cabanela, MD; Duane Ilstrup, MS; and Robert M. Wachter, MD, for the Hospitalist–Orthopedic Team Trial Investigators

Background: **Hospitalists are assuming an increasing role in the care of surgical patients, but the impact of this model of care on postoperative outcomes is unknown.**

Objective: **To determine the impact of providing a collaborative, hospitalist-led model of care on postoperative outcomes and costs among patients having hip or knee arthroplasty.**

Design: **Randomized, controlled trial.**

Setting: **Academic medical center.**

Participants: **526 patients having elective orthopedic surgery who are at elevated risk for postoperative morbidity.**

Measurements: **Length of stay, inpatient postoperative medical complications, health care provider satisfaction, and inpatient costs.**

Interventions: **A comanagement medical Hospitalist–Orthopedic Team compared with standard postoperative care by orthopedic surgeons with medical consultation.**

Results: **More patients in the hospitalist group were discharged from the hospital with no complications (61.6% vs. 49.8%; difference, 11.8 percentage points [95% CI, 2.8 to 20.7 percentage points]). Fewer minor complications were observed among hospitalist patients (30.2% vs. 44.3%; difference, −14.1 percentage points [CI, −22.7 to −5.3 percentage points]). Observed length of stay was not statistically different between treatment groups. However, when adjusted for discharge delays, mean length of stay for patients in the hospitalist model of care was shorter (5.1 days vs. 5.6 days; difference, −0.5 day [CI, −0.8 to −0.1 day]). Total costs did not differ between groups. Orthopedic surgeons and nurses preferred the hospitalist model.**

Limitations: **Care providers and patients were aware of intervention assignments, and the study could not capture all costs associated with the hospitalist model.**

Conclusions: **The comanagement medical Hospitalist–Orthopedic Team model reduced minor postoperative complication rates with no statistically significant difference in length of stay or cost. The nurses and surgeons strongly preferred the comanagement hospitalist model. Additional research on the clinical and economic impact of the hospitalist model in other surgical populations is warranted.**

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For author affiliations, see end of text.
See editorial comment on pp 67-69.

Hospitalists are increasingly delivering inpatient care. Fueled by data supporting improved efficiency with improved quality, there are now 6000 hospitalists in the United States, with expected growth to nearly 20 000 (1, 2). The hospitalist's traditional role has expanded beyond the care of hospitalized medical patients (3–5). In many systems, hospitalists have partnered with surgeons to provide perioperative care. In a national survey, 44% of hospitalists reported serving as the primary physician for surgical patients (6).

Other studies have analyzed the effects of hospitalist models on patient outcomes in medical settings (7–16). We sought to identify their impact in a surgical setting. Specifically, a multidisciplinary, collaborative Hospitalist–Orthopedic Team was compared with standard orthopedist-managed practice in the care of patients undergoing elective lower-extremity joint replacement. Primary end points were perioperative medical morbidity and length of hospitalization; secondary end points were patient and provider satisfaction and direct costs of hospital care.

Methods

We conducted a randomized, controlled trial at Rochester Methodist Hospital, a tertiary care, primarily surgical, teaching hospital with 794 beds and an average of more than 15 000 admissions per year. The Department of Orthopedic Surgery consists of 46 faculty surgeons and 50 residents. Twelve of the faculty surgeons perform lower-extremity major joint procedures at Rochester Methodist Hospital. The orthopedic residents rotate with the faculty for blocks of 3 months. We obtained institutional review board approval to conduct this study.

Participants

Patients undergoing elective adult primary or revision total knee or hip arthroplasties (diagnosis-related group 209) who were at elevated risk for perioperative complications were eligible for participation. Patients older than 75 years of age with either 1 or more major comorbid conditions or 2 or more less disabling comorbid conditions were considered at elevated risk. Major comorbid conditions were diabetes mellitus, congestive heart failure, history of

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coronary artery bypass grafting (CABG), history of myocardial infarction, history of stroke, dementia, immunosuppression, severe chronic obstructive pulmonary disease, substantial renal insufficiency with a serum creatinine level greater than 176.80 μmol/L (2.0 mg/dL) or use of dialysis, obstructive sleep apnea, or severe atherosclerosis obliterans. Less disabling comorbid conditions were hypertension, cardiac arrhythmia, history of venous thromboembolic disease or other coagulation abnormality, mild chronic obstructive pulmonary disease, or mild renal insufficiency (serum creatinine level between 123.76 and 176.80 μmol/L [1.4 and 2.0 mg/dL]). Patients younger than 18 years of age, non-U.S. residents, and inmates of the local correctional facility at the time of surgery were excluded.

Interventions

Consent and Randomization

We identified patients during their initial outpatient orthopedic evaluation. Before surgery, the nurse study coordinator asked patients to participate, and the patients provided written consent for trial participation and access to their medical and administrative records. We used concealed, computerized dynamic allocation (17) to randomly assign patients and to maintain balance between study groups within the 4 strata: primary hip, revision hip, primary knee, and revision knee arthroplasty (18–20). The study coordinator entered relevant procedure information for each enrolled patient, and the program returned the study group assignment. The dynamic allocation process randomly assigned the first enrolled patient in each stratum to 1 of the study groups. Each new patient was assigned to the study group with the fewest patients in the appropriate stratum.

The Hospitalist–Orthopedic Team model required nurses and surgeons to know whom to call with patients' medical concerns; therefore, we could not blind providers. Because hospitalists saw patients daily and responded directly to medical concerns, the treatment group was also apparent to patients and families.

Trial Pilot Phase

We allowed for a 2-week pilot phase to evaluate whether changes in process and implementation of the study protocol could improve the efficiency and accuracy of this effort. Therefore, as per protocol, we removed patients in the pilot phase from the analyzed cohort because they may have been exposed to a different process of study implementation.

Standard Care and Comanagement Care

We randomly assigned trial participants to either the standard orthopedic practice or the Hospitalist–Orthopedic Team model (**Table 1**). Certain aspects of care delivery were similar between the 2 models of care. These included composition of orthopedic surgical team; nursing personnel; anesthetic care; deep venous prophylaxis; and initial postoperative recovery care, including hemoglobin levels and electrolytes in the 2 to 3 days after surgery. The study protocol did not influence the room allocation of the patients. In both groups of the trial, patients undergoing total hip or knee arthroplasties were placed on the respective postoperative clinical pathway, which was developed by the orthopedic surgical department several years before this study. This pathway includes recommendations for routine postoperative laboratory studies, initiation of physical therapy, and nursing education. In addition, standard nurse-directed protocol for urinary catheter management was used for all patients. This included suprapubic ultrasound determination of urinary retention and guidelines for nursing-initiated urinary catheterization. The standard postoperative order set used in both groups included vital sign and temperature monitoring, medication regimens for pain control, pulmonary hygiene, diet, and activity.

In the standard model of perioperative care, the orthopedic surgical team was responsible for any postoperative patient issue that required additional diagnostic evaluation or treatment throughout the hospitalization. For example, work-up of fever, shortness of breath, nausea, or chest pain was at the discretion of the orthopedic residents under the supervision of their faculty. Nurses directed all concerns (medical or surgical) to orthopedic surgery residents. Subspecialty medical consultation was at the discretion of the orthopedists; the subspecialist typically saw patients once daily, as needed, until the medical condition in question resolved or stabilized. These subspecialty consulting teams provide written recommendations in the medical record and, in most cases, do not actually write orders, help prepare discharge summaries, or participate in discharge planning or contacting local referring physicians.

The Hospitalist–Orthopedic Team model of perioper-

Context

No large studies evaluate potential benefits and costs of internists and surgeons comanaging postoperative patients.

Contribution

In this single-center trial, high-risk patients undergoing elective hip or total knee arthroplasty were randomly assigned to either standard surgical care or comanagement care by a team of general internal medicine faculty and orthopedic physicians and nurses. Compared with standard care, comanagement care reduced the number of postoperative complications but did not affect overall length of stay or costs. Clinicians strongly preferred comanagement care.

Cautions

Costs of comanagement were not captured fully because physician–patient interaction time was not tracked.

–The Editors

Table 1. **Standard Care and Comanagement Care**

Aspects of Patient Care	All Care	Standard Care	Comanagement Care
Care team			
Composition of orthopedic surgery team	Orthopedic surgery faculty and resident		
Composition of medical team		Consultative medical specialty teams (faculty and resident)	Hospitalist faculty (no residents); consultative medical specialty teams (faculty and resident)
Nursing personnel	Predominantly registered nurses on 1 of 2 specific orthopedic surgical floors		
Direct patient care			
Preanesthetic medical examination		General internist, medical subspecialist, or anesthesiologist	Hospitalist
Daily patient evaluation during hospitalization		Orthopedic surgical team	Hospitalist–Orthopedic surgical team
Perioperative medical care		Orthopedic surgical team	Hospitalist
Subspecialty medical consultation		Discretion of orthopedic surgical team	Discretion of hospitalist
Responsible team to nurses' postoperative patient care concerns		Orthopedic surgical team	Hospitalist (medical issues); orthopedic surgical team (surgical issues)
Discharge responsibilities		Surgeons contact referring physician	Hospitalist contacts primary medical physician; orthopedic surgical team contacts surgical/referring physician
		Surgeons complete discharge summary	Both surgeons and hospitalists complete respective portions of discharge summary
Laboratory tests and medications			
Surveillance for and prophylaxis against deep venous thrombosis	Orthopedic surgical team		
Initial postoperative laboratory and medical orders	Orthopedic surgeons with standard postoperative order set		

ative care was designed to integrate general internal medicine faculty hospitalists with the orthopedic surgical team (largely interfacing with the surgical residents) and the orthopedic surgery nurses. Three hospitalists rotated throughout the study year to provide clinical care. The mean length of postgraduate clinical experience for the hospitalists was 6.2 years. Their duties also included medical consultation for nonorthopedic patients and care of patients in a transitional skilled-nursing facility. Unlike standard practice, the hospitalists (rather than the orthopedic surgeons) provided all indicated postoperative medical care after the surgical team completed initial postoperative orders. The hospitalists frequently saw patients more than once daily and wrote orders (for example, for laboratory tests, fluid and electrolyte management, and medications).

Outcomes Assessment

Primary outcomes were inpatient postoperative overall medical complication rate and hospital length of stay. The study nurse identified the occurrence of a complication through chart abstraction from laboratory and test results as well as medical records. Postoperative medical complications were categorized a priori into composite end points, including major (death, myocardial infarction, renal failure requiring dialysis, or respiratory failure–required ventilatory support), intermediate (congestive heart failure, pulmonary embolus, ileus, or pneumonia), or minor (electrolyte abnormalities, fever, or urinary tract infection) to allow for subanalysis (**Appendix Table**, available at www.annals.org). These complications were assessed on the basis of confirmable, objective criteria (laboratory and test results). For patients with multiple complications, only the most severe one was included. Surgical complications (wound infection, hemarthrosis, hematoma, dislocation, or prosthesis failure) were not included as a study end point. We defined hospital mortality as any death during hospitalization for the incident procedure.

Length of stay was assessed in 2 ways: unadjusted (days from admission to discharge) and adjusted (days from admission to the date when there was documented consensus among all hospital staff, including nurses, social workers, surgeons, and hospitalists, that the patient was ready for discharge, pending appropriate skilled-nursing placement). The study coordinator assessed these data on potential dismissal date through medical record review of the independent notes from each health care provider.

There were no missing data on the primary outcomes or relevant covariates used in study analyses.

Sample Size Calculation

Retrospective review of administrative data for diagnosis-related group 209 established a mean (±SD) length of stay of 5 ± 1.5 days and an estimated medical complication rate of 20%. Our recruitment goal was 450 patients (225 in each group), which would provide 80% power for detecting as significant a 45% reduction in all-cause complications (20% vs. 11%) and 80% power for detecting as significant a 0.4-day reduction in length of stay, assuming an α value of 0.05 (2-sided tests).

Secondary Outcomes

Patient satisfaction questionnaires that have been used successfully in other studies (21) were distributed and collected on the day of discharge. This survey assesses patient satisfaction with overall care and willingness of caregivers to listen and address questions on a 5-point Likert scale (1 = poor; 5 = excellent). Nurses, orthopedic residents, and faculty surgeons were confidentially surveyed regarding their preferences between the standard care and Hospitalist–Orthopedic Team care models. The questions assessed preferences between models in areas such as comparative ease of providing high-quality care, including coordination of patients' medical care, promptness in addressing postoperative case issues, and perceptions of the quality of patients' overall care. Preferences were scored on a centered 5-point scale, ranging from "Hospitalist–Orthopedic Team much better" to "standard orthopedic practice much better." Results were reported in the percentage distribution of responses. The detail of all responses provided by nurses has been published elsewhere (22). Providers were surveyed quarterly, with postcard reminders sent 2 weeks after the initial mailing. In the case of a nurse or surgeon responding more than once during the study year, we analyzed each provider's most recent response.

We used administrative data to estimate hospital and physician costs incurred by enrolled patients during hospitalization. A standardized, year 2000 constant-dollar cost estimate was assigned to each service using the Medicare Part A and Part B classification system (23, 24). Specifically, Part A billed charges were adjusted by using hospital department cost-to-charge ratios and wage indexes, and Part B physician service costs were proxied by 2000 Medicare reimbursement rates.

Data Entry

Data was entered by using online data entry screens created within the SAS generalized system (SAS Institute, Inc., Cary, North Carolina). Preprogrammed edit-checking procedures ensured accurate data entry.

Statistical Analysis

Patient characteristics (demographic, American Society of Anesthesiologists [ASA] class, surgical procedure, medical morbidity) and in-hospital, postoperative medical complication rates between the 2 study groups were compared by using chi-square tests. To compare the severity of complications (none, minor, intermediate, or severe) between groups, we used a Mantel–Haenszel chi-square test using ridit ("relative to an identified distribution") scores to account for the ordinal nature of the severity of complications (25, 26). Differences in hospital length of stay were compared by using rank-sum tests with CIs based on the nonparametric bootstrap (27). Results from logistic and linear rank regressions for primary outcomes, adjusting for stratification factors (hip or knee arthroplasty and primary or revision surgery) (28, 29), revealed statistical significance similar to that of our unadjusted analysis and thus are not presented.

We analyzed provider preferences using a 1-sample signed-rank test that assessed difference from zero. Patient satisfaction was analyzed with a Wilcoxon rank-sum test. Exploratory analyses were conducted to investigate whether intervention effects varied by preoperative risk. These ancillary analyses were not specified in the protocol but were planned before data review and were performed by using linear and logistic regression models with terms for intervention, baseline ASA, and intervention by baseline ASA interaction. Mean hospital, physician, and combined costs were compared by using *t*-tests, the Z-score method (which accounts for skewness in cost data), and the nonparametric bootstrap (27, 30, 31). All statistical tests were 2-sided, and P values less than 0.05 were considered significant. SAS software, version 8.2 (SAS Institute, Inc.), was used for randomization and all analyses.

Role of the Funding Source

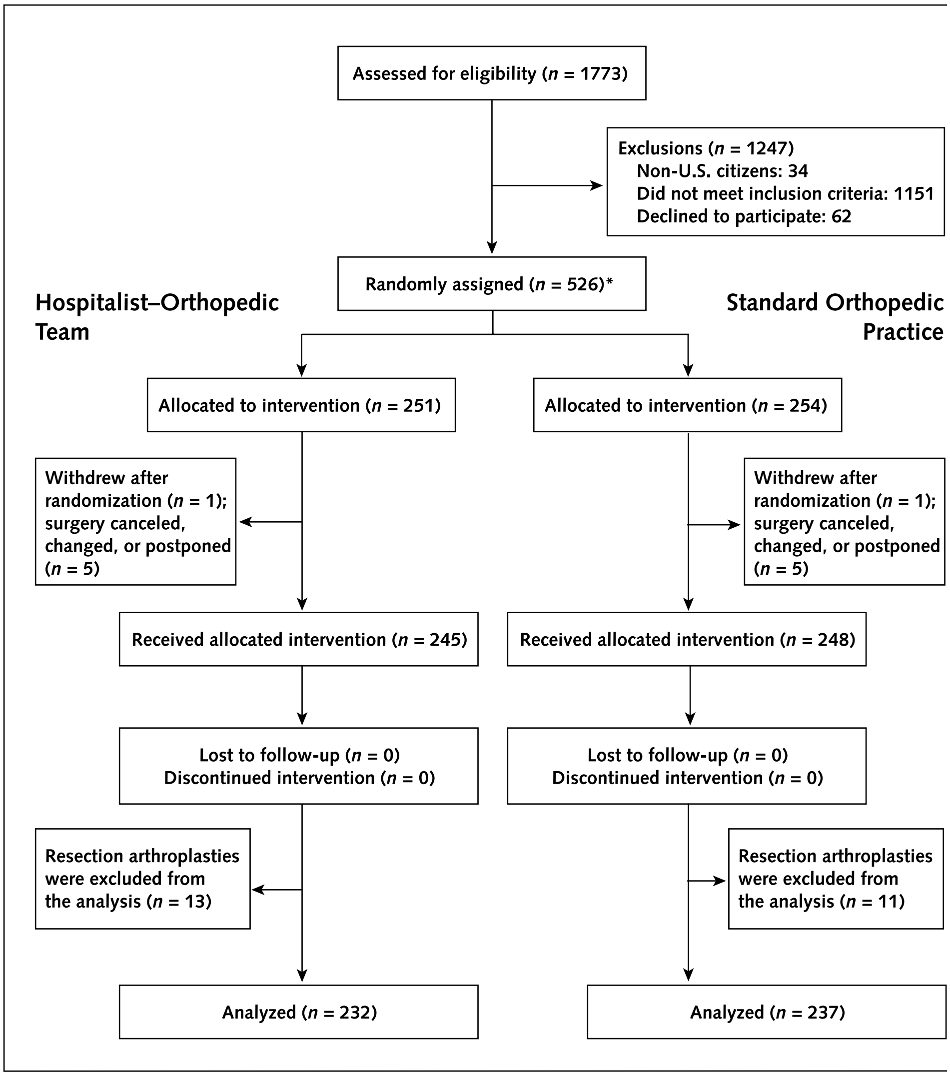
Our study was funded through a competitive grant for clinical research studies from the Mayo Foundation. This competitive intramural source is designed to foster scientific work by clinician investigators and expects research results to be published. The funding source placed no stipulations in protocol development, collection, and interpretation of the data or on the operational aspects of the study.

Results

Participant Flow

As shown in **Figure 1**, 1773 patients underwent total hip or knee arthroplasty between 1 July 2000 and 30 June 2001. Of these, 588 met inclusion criteria, and 62 declined participation. The 526 patients signed consent forms and were randomly assigned to either the Hospitalist–Orthopedic Team or standard orthopedic practice model. The 2-week pilot phase did not reveal any necessary changes to study protocol implementation. However, as specified in our protocol, we excluded 21 patients randomly assigned during this pilot period from analysis. Of the remaining patients, surgery was canceled, changed, or postponed beyond the study period in 10 patients. One of these patients was excluded after randomization because of a change in surgical procedure (patellar replacement only). Two patients withdrew from the study after randomization but before intervention. Twenty-four patients undergoing only a hip or knee staged prosthetic resection and delayed reimplantation for infection were also excluded because pat-

Figure 1. **Flow of patients through the trial.**



*Twenty-one patients randomly assigned in the pilot study were not included in the analysis.

terns of care (2 surgical procedures versus 1; extended period with no joint during antibiotic administration) in this group were substantially different from those observed in the remaining sample. This left 232 patients in the Hospitalist–Orthopedic Team group and 237 patients in the standard orthopedic practice group available for analysis. One in-hospital death in the standard orthopedic practice group was included in the analysis of complication rates but excluded from length of stay assessment.

No significant differences in age, sex, and preexisting comorbid conditions were detected between the groups. Patients were distributed similarly across ASA classification (32), which was determined independently at the time of surgery by anesthesiologists blinded to the study. **Table 2** presents characteristics of the analysis cohort by intervention group.

The most frequent postoperative complications were electrolyte abnormalities, postoperative fever, and urinary tract infections (30%, 13%, and 4%, respectively). Surgical complication rates were similar in the 2 groups (8.2% in Hospitalist–Orthopedic Team vs. 11.0% in standard orthopedic practice; difference, −2.8 percentage points [CI, −8.2 to 2.7 percentage points]). With the exception of fewer neurology consultations in the Hospitalist–Orthopedic Team model (0.9% vs. 4.6%; difference, −3.7 percentage points [CI, −6.9 to −0.6 percentage points]), the rate of subspecialty medical consultations was also similar for both groups.

Table 3 shows the effects of the Hospitalist–Orthopedic Team model of care on inpatient morbidity, hospital length of stay, and direct medical costs. More patients in the Hospitalist–Orthopedic Team group were discharged from the hospital without complications (61.6% vs. 49.8%; difference, 11.8 percentage points [CI, 2.8 to 20.7 percentage points]). The severity of complications was statistically different between the 2 groups ($P = 0.03$). Pa-

Table 2. **Characteristics of Analyzed Patient Cohort**

Characteristic	Hospitalist–Orthopedic Team*	Standard Orthopedic Practice*
Patients, *n (%)*	232 (49.5)	237 (50.5)
Mean age ± SD, *y*	72.6 ± 10.6	73.7 ± 8.7
Sex, *n (%)*		
Male	105 (45)	112 (47)
Female	127 (55)	125 (53)
Surgical procedure, *n (%)*		
Primary total hip arthroplasty	72 (31)	67 (28)
Revision total hip arthroplasty	47 (21)	53 (22)
Primary total knee arthroplasty	89 (38)	93 (39)
Revision total knee arthroplasty	24 (10)	24 (10)
American Society of Anesthesiologists classification, *n (%)*		
I	1 (0)	2 (1)
II	103 (44)	98 (41)
III	120 (52)	134 (57)
IV	8 (3)	3 (1)
Medical comorbid conditions (history), *n (%)*		
Diabetes	53 (22.8)	38 (16.0)
Congestive heart failure	13 (5.6)	16 (6.8)
Coronary artery disease	98 (42.5)	102 (43.0)
Dementia	4 (1.7)	6 (2.1)
Chronic obstructive pulmonary disease	33 (14.2)	30 (12.7)
Immunosuppression	26 (11.2)	34 (14.4)
Renal failure or dialysis	28 (12.0)	25 (10.6)
Deep venous thrombosis or pulmonary embolus	28 (12.0)	42 (17.7)
Cerebrovascular accident or transient ischemic attack	24 (10.3)	13 (5.5)
Peripheral vascular disease	8 (3.5)	11 (4.6)

* Chi-square tests. No statistical difference was found between the 2 study groups in any category.

tients in the Hospitalist–Orthopedic Team group had fewer minor complications (30.2% vs. 44.3%; difference, −14.1 percentage points [CI, −22.7 to −5.3 percentage points]), whereas the frequency of intermediate complications (6.9% vs. 4.6%; difference, 2.3 percentage points [CI, −2.1 to 6.6 percentage points]) and major complications (1.3% vs. 1.3%; difference, 0 percentage points [CI, −2.3 to 2.4 percentage points]) was similar for patients in the 2 study groups.

We found no statistically significant difference in mean unadjusted length of stay (5.6 vs. 5.7 days; difference, −0.1 day [CI, −0.5 to 0.2 day]). However, patients were deemed ready for discharge sooner with the Hospitalist–Orthopedic Team model of care and had a shorter adjusted length of stay (5.1 vs. 5.6 days; difference, −0.5 day [CI, −0.8 to −0.1 day]).

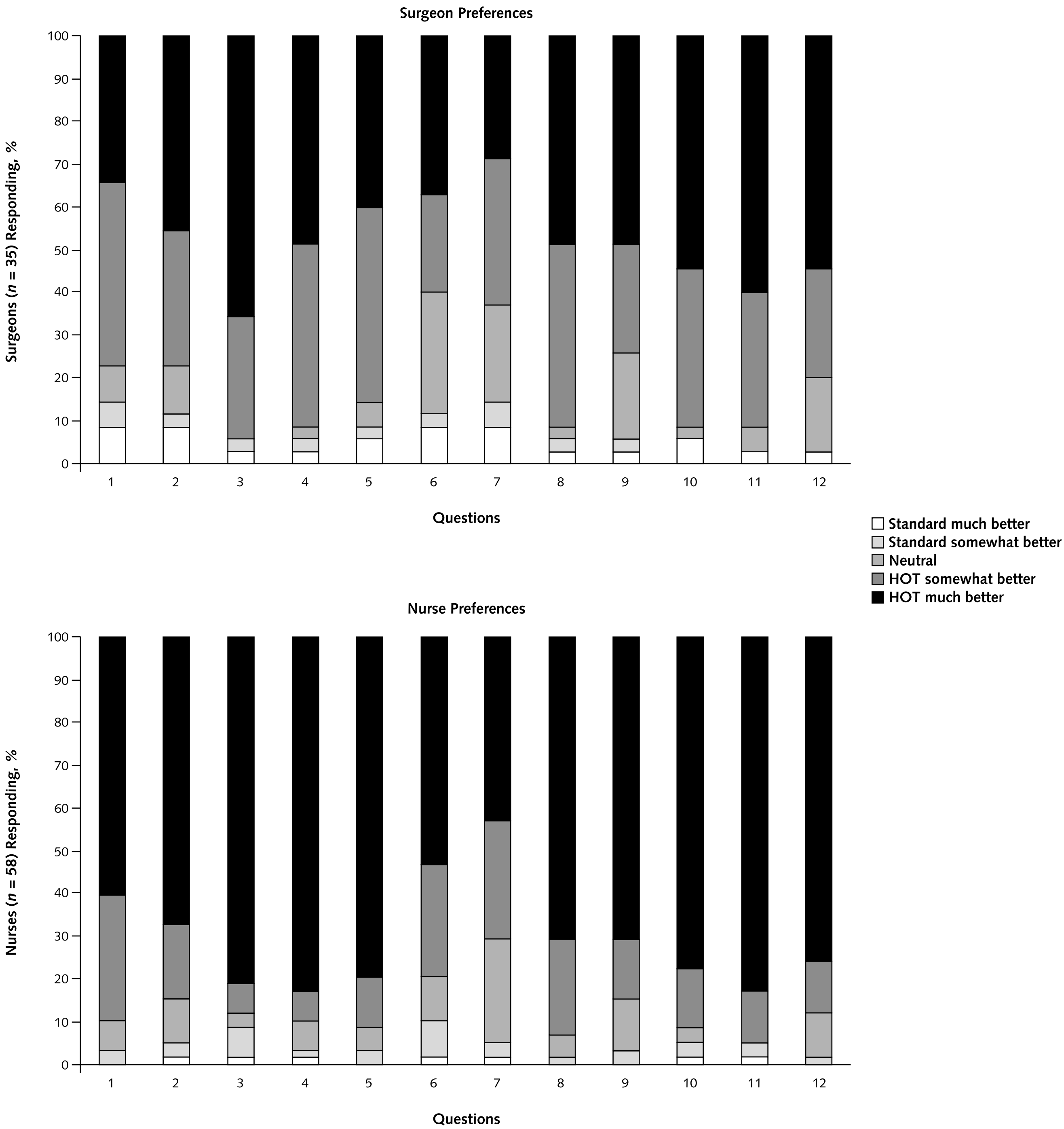
Estimated physician costs were higher in the Hospitalist–Orthopedic Team group ($2689 vs. $2367; difference, $322 [CI, $175 to $484]), although hospital costs and total medical costs did not vary substantially between groups ($12 684 vs. $12 916; difference, −$232 [CI, −$1096 to $636], and $15 373 vs. $15 283; difference,

Table 3. **Comparison of Primary and Secondary Outcomes**

Outcome Measure	Hospitalist–Orthopedic Team (*n* = 232)	Standard Orthopedic Practice (*n* = 237)	Difference (95% CI)	*P* Value
Any complication, *n (%)*				
No	143 (61.6)	118 (49.8)	11.8 (2.8 to 20.7)*	0.01
Yes	89 (38.4)	119 (50.2)		
Complications by severity, *n (%)*				
None	143 (61.6)	118 (49.8)	11.8 (2.8 to 20.7)*	0.03
Minor	70 (30.2)	105 (44.3)	−14.1 (−22.7 to −5.3)*	
Intermediate	16 (6.9)	11 (4.6)	2.3 (−2.1 to 6.6)*	
Major	3 (1.3)	3 (1.3)	0.0 (−2.3 to 2.4)*	
Mean hospital length of stay, *d*†				
Observed	5.6	5.7	−0.1 (−0.5 to 0.2)	0.06
Adjusted	5.1	5.6	−0.5 (−0.8 to −0.1)	<0.001
Mean direct medical costs, $‡				
Hospital costs	12 684	12 916	−232 (−1096 to 636)	>0.2
Physician costs	2689	2367	322 (175 to 484)	<0.001
Total costs	15 373	15 283	90 (−887 to 1067)	>0.2

* Differences are expressed as percentage points.
† Patient who died in standard orthopedic practice was excluded from length-of-stay analysis; bootstrapped 95% CI used the percentile method.
‡ In 2000 constant U.S. dollars; bootstrapped 95% CI used the percentile method; reported *P* value used Z-score method.

Figure 2. **Surgeon (*top*) and nurse (*bottom*) preferences.**



The 12 questions presented in the Care Model Assessment questionnaire were as follows (phrases and questions represent exact wording in the questionnaire): 1) general level of communication between all medical care providers; 2) recommendations and questions are brief and specific from the medical physicians; 3) ease of asking for advice from medical physicians at St. Mary's Hospital; 4) ease of providing high-quality medical care; 5) coordination of patients' postoperative medical care; 6) clarity of "who is in charge" of postoperative medical care; 7) coordination of patients' dismissal; 8) recognition of postoperative medical needs of the patient; 9) for medical physicians associated with the unit, general knowledge of perioperative care issues; 10) the patient receives better care; 11) promptness with which patients' postoperative medical care issues are addressed; and 12) results of tests, labs, and procedures are followed up on. HOT = Hospitalist–Orthopedic team.

$90 [CI, −$887 to $1067]). Nurses and orthopedic surgeons strongly preferred the Hospitalist–Orthopedic Team model (2). Patient satisfaction did not differ between the groups in any of the domains.

Ancillary Analysis

For the exploratory analyses examining intervention effect by level of preoperative risk, patients were combined into a low ASA group (ASA class I or II; $n = 204$) and high ASA group (ASA class III or IV; $n = 265$). For those in the low ASA group, more patients in the Hospitalist–Orthopedic Team group were discharged without complications (68.3% vs. 46.0%; difference, 22.3 percentage points [CI, 8.6 to 35.1 percentage points]). For those in the high ASA group, the percentage of patients free of complications was similar (56.3% vs. 52.6%; difference, 3.7 percentage points [CI, −8.4 to 15.6 percentage points]). There was evidence of an interaction between ASA group and intervention, as assessed with the logistic model ($P = 0.04$).

For those in the low ASA group, unadjusted length of stay was shorter in the Hospitalist–Orthopedic Team group than in the standard practice group (5.4 days vs. 5.8 days; difference, −0.4 day [CI, −0.9 to −0.01 day]). For those in the high ASA group, unadjusted length of stay was similar (5.8 days vs. 5.7 days; difference, 0.1 day [CI, −0.5 to 0.6 day]). There was no evidence of an interaction between ASA group and intervention, as assessed in the linear model ($P = 0.179$). Length of stay, adjusted for delayed discharges, was shorter for patients in the Hospitalist–Orthopedic Team group for the low ASA group (4.9 days vs. 5.6 days; difference, −0.7 day [CI, −1.1 to −0.4 day]) and for the high ASA group (5.3 days vs. 5.6 days; difference, −0.3 day [CI, −0.6 to 0.3 day]). There was borderline evidence of an interaction between ASA group and intervention, as assessed with the linear model ($P = 0.052$).

Discussion

Our randomized, controlled trial demonstrated that patients cared for by the Hospitalist–Orthopedic Team were more likely to be discharged without medical postoperative complications. Although we found no statistically significant difference in mean unadjusted length of stay, when we accounted for delays in discharge secondary to lack of beds at a skilled-nursing home, we found that patients were ready for discharge sooner when cared for by hospitalists. Total costs (physician and hospital components) did not differ between the 2 models of care. Both nurses and surgeons preferred the Hospitalist–Orthopedic Team model of care.

To our knowledge, this is the first study to evaluate the effect of the hospitalist model or other medical and surgical partnerships in the care of elective orthopedic surgical populations in today's health care environment. Medical and orthopedic partnerships have been explored, but not specifically including hospitalists. Studies in the 1970s and 1980s documented improved clinical outcomes with a geriatrician and orthopedic surgeon interface (33–35). These models were reported only in urgent hip fracture surgical populations in an era when length of postoperative hospital stay commonly exceeded 3 weeks.

Although no earlier studies have documented the clinical outcome benefits in surgical patients, a growing body of literature suggests that medical patients have improved outcomes when hospitalists provide care compared with a more traditional generalist (combined inpatient and outpatient practice) model (36–39). We did not have the power to detect statistical differences in severe morbidity or mortality but did find that fewer total postoperative complications occurred in the hospitalists' patient population. We attribute this largely to the overall reduction in minor complications (electrolyte abnormalities, urinary tract infection, and fever). This reduction, although of unknown clinical significance, probably resulted from active management of urinary catheters and postoperative fluids (beyond the standard postoperative orders), more routine follow-up, and close surveillance. Other possible mechanisms include around-the-clock availability of hospitalists to nurses, which led to an increase in direct communication. As suggested by Meltzer and colleagues (39), higher disease-specific experience in medical patients improves clinical outcomes. Although not studied to date, this volume-related experience in perioperative care among hospitalists may also help decrease postoperative medical complications.

Previous research has demonstrated efficiency of hospitalists measured by reduction in length of stay for medical patients (10, 14–16, 36, 39–42). We did not observe a statistically significant decrease in length of stay ($P = 0.06$) during the first year of program implementation. Similarly, 2 recently published studies found no statistically significant difference in length of stay during the first year of implementation of the hospitalist model but did find significant differences in the second year of their respective programs (36, 39). It is possible that surgical complications could prolong length of stay independent of medical management. Our data, however, revealed no difference in postoperative surgical complication rates between the 2 groups. The half-day difference in length of stay in the analysis, adjusted for discharge delays secondary to lack of beds at a skilled-nursing home, may improve patient flow by opening up a bed for a new postoperative patient. Realizing this efficiency hinges on hospital bed demand as well as an ability to minimize shortages of beds at skilled-nursing homes. Therefore, some practitioners may not find our adjusted length of stay results to be of significance in their settings because of the effort and expense of setting up a comanagement model of postoperative care.

Previous studies have reported mixed results regarding subspecialty consultations under hospitalist models (10, 13, 15). A reduction in specialty consultation has obvious financial implications for specialists. If appropriate consultations are not called, quality may suffer. With the exception of neurologic consultations, we found no change in subspecialty consultation rates. The difference in neurologic consultations may be related to the hospitalists' experience with managing geriatric postoperative delirium.

To our knowledge, no other published study has evaluated nurses' or surgeons' preferences about the hospitalist model of care. Our health care provider satisfaction survey established that both nurses and orthopedic surgeons strongly preferred the multidisciplinary, integrated, and collaborative Hospitalist–Orthopedic Team model to standard perioperative care. With the Hospitalist–Orthopedic Team model, providers reported that postoperative medical care was prompt and coordinated and that there was a sense of enhanced ease of providing care. Because of persistent nationwide nursing shortages, the implications of these preferences for nursing retention are of potential increased importance.

Our standardized cost results are more generalizable than those based on unadjusted billed charges, but the services provided do represent our institution's clinical practice patterns. Furthermore, the cost analysis was performed from the provider perspective and relied on administrative data sources to track utilization and associated cost of care incurred by study participants during hospitalization. A key limitation of this approach is the inability to completely capture all costs associated with a hospitalist model, namely, the actual physician–patient interaction time, because of current billing restrictions. For example, Medicare will allow only 1 billed internist encounter per day even though hospitalists may see patients many times throughout a day depending on their on-site availability. We observed higher professional costs, probably because the hospitalist was involved in patient care. However, we may have underestimated this cost difference because we could not fully capture physician–patient interaction time. Anecdotally, physicians in our hospitalist model typically visited patients twice a day. Had we been better able to completely capture costs associated with this time commitment, the observed professional cost difference in our analysis may have been even greater. Future studies should consider time motion methods to provide more thorough estimates of the costs associated with a hospitalist model. Ongoing research is being conducted to assess differences in health care utilization up to 1 year after discharge. A better understanding of the long-run cost-effectiveness of the Hospitalist–Orthopedic Team model is important because it is unknown whether complications or mortality differ after discharge.

Generalizability of trial results from our academic, multispecialty group practice in a largely white community is always problematic; this is particularly true with a new, diverse, and evolving model of care. Programs are developed within the constraints inherent in the respective hospital setting. Because our standard practice has greater access to subspecialty consultations than does a typical community hospital, we may not correctly estimate the impact of implementing a Hospitalist–Orthopedic Team model in other settings that have less subspecialty access. Because no published data compare clinical outcomes of hospitalists versus subspecialists, we cannot hypothesize whether the availability of subspecialty consultations affects clinical outcomes associated with the hospitalist model of care. However, in a model in which the hospitalists do not have access to subspecialty consultations, the burden of medical care in partnership with surgeons would fall to the hospitalists.

Our study has several limitations. Varying clinical documentation patterns between the hospitalists and the surgeons may bias the recording of complications. To minimize potential bias, we included only those complications that could be defined by objective standards (for example, laboratory, electrocardiographic, radiographic, or echocardiographic). Physicians' independent documentation of a complication by itself was insufficient to identify postoperative medical complications. On the other hand, we recognize that reliance on laboratory and test results to document complications may in itself impose bias because of varying patterns of test ordering and surveillance by the hospitalists and the surgeons. Our analysis revealed no statistical difference in volumes of urinalyses and laboratory studies ordered in either group of the study. Use of hard end points was particularly essential because of another important limitation of the study: The primary investigator served as one of the practicing hospitalists in this study. Finally, another limitation in our study was the inability to blind participants and health care providers to the treatment model assigned. A central feature of the Hospitalist–Orthopedic Team model of care is tight integration and collaboration across disciplines and departments. The presence of the hospitalists in the care of patients was very visible to all health care providers, patients, and their families.

Standard postoperative care at our institution emphasizes a tightly managed clinical pathway that standardizes routine laboratory investigations (for example, hemoglobin and electrolytes) and physical therapy. In this type of setting, any new models of care aimed at efficiency require explicit deviation from this established pathway. Results of implementing the Hospitalist–Orthopedic Team model in institutions where standard care is not as tightly managed may differ (43). Adding a hospitalist program in an institution where the timing of clinical processes varies more could enhance the operational efficiency by decreasing delays in clinical evaluation, therapy, and discharge. Additional work is needed to understand interactions between hospital systems of care and hospitalists in varying settings.

The Hospitalist–Orthopedic Team model of perioperative care effectively reduced minor medical complications in patients at risk for postoperative morbidity. Furthermore, under the Hospitalist–Orthopedic Team model, more patients left the hospital with no complications. Observed length of stay was not significantly different between models of care. However, adjusting length of stay for shortage of community nursing home beds resulted in shorter hospital lengths of stay under the Hospitalist–Orthopedic Team model of care. We found no statistically significant difference in observed total direct medical costs. Additional research is needed to understand the mechanisms by which the Hospitalist–Orthopedic Team model achieved its effects, as well as the impact of collaborative hospitalist–surgeon models across diverse target populations and hospital settings.

From Mayo Clinic College of Medicine, Rochester, Minnesota, and the University of California, San Francisco, San Francisco, California.

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Requests for Single Reprints: Jeanne M. Huddleston, MD, Mayo Clinic, 200 First Street Southwest, Rochester, MN 55905; e-mail, huddleston.jeanne@mayo.edu.

Current author addresses are available at www.annals.org.

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Current Author Addresses: Drs. Huddleston, Long, Trousdale, Cabanela, and Naessens, Mr. Larson, Mr. Plevak, and Mr. Ilstrup: Mayo Clinic, 200 First Street SW, Rochester, MN 55905.
Dr. Vanness: University of Wisconsin–Madison, 785 WARF Building, 610 Walnut Street, Madison, WI 53726.
Dr. Wachter: University of California, San Francisco, 400 Parnassus Avenue, San Francisco, CA 94143.

Appendix Table. **Definitions of Postoperative Complications**

Medical Complications	Definitions
Severe	
Death	Inpatient death
Respiratory failure	Mechanical ventilation for >24 h postoperatively or need for reintubation
Pulmonary embolus	High-probability ventilation–perfusion scan, positive spiral computed tomography scan, or positive pulmonary angiogram
Acute myocardial infarction	New Q wave (0.4 sec wide and 1 mm deep); elevated troponin I level; increase of the creatine kinase–MB level, consistent with myocardial infarction
Renal failure	Need for dialysis
Intermediate	
Pneumonia	Infiltrate on chest radiograph and symptom complex (cough with or without dyspnea)
Congestive heart failure	Peripheral edema or basilar crackles on pulmonary examination and study findings (chest radiograph with cephalization or effusions or echocardiogram with decreased ejection fraction or diastolic dysfunction)
Deep venous thrombosis	Positive finding on lower-extremity venous Doppler ultrasonography
Acute central nervous system event (transient ischemic accident or cerebrovascular accident)	Transient or permanent central nervous system deficit
Delirium	Confusion assessment method requires the presence of features 1, 2, and 3 and either 4 or 5: 1 = acute change in mental status 2 = fluctuating symptoms 3 = inattention 4 = disorganized thinking 5 = altered level of consciousness
Ileus	Abdominal radiograph with dilated small bowel, consistent with adynamic ileus
Gastrointestinal bleeding	Endoscopic evidence of gastrointestinal bleeding
Minor	
Urinary tract infection	Urinalysis with pyuria or positive Gram stain and symptoms (dysuria, increased frequency of urination)
Postoperative fever	Temperature >38 °C on 2 occasions in a 24-h period (excluding first 24 h)
Electrolyte abnormalities	Any potassium or sodium level outside the institutional ranges of normal values