An Operative Risk Management Pathway to Increase Perioperative β-Blocker Utilization in Patients Undergoing Elective Total Hip or Knee Arthroplasty

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Abstract

- **Objective:** To assess the impact of an operative risk management pathway that promotes the use of perioperative β-blockers.
- **Methods:** A before and after intervention cohort study was conducted at a tertiary care referral center.
- **Results:** Data from 300 consecutive preintervention and 300 consecutive postintervention total hip and knee arthroplasty patients were gathered. Perioperative β-blocker use increased from 18% to 60% (P < 0.001), with a corresponding reduction in cardiovascular complications (11% versus 1.1%; P < 0.001). The rates of cardiac ischemia (7% versus 1%; P < 0.001), myocardial infarction (3% versus 1%; P = 0.038), angina (4% versus 1%; P = 0.002), congestive heart failure (4% versus 0%; P < 0.001), and hospital length of stay (3.55 days versus 3.9 days; P = 0.005) were reduced in the postintervention group.
- **Conclusion:** An operative risk management pathway promoting the use of perioperative β-blockers was effective for increasing appropriate utilization of perioperative β-blockers and reduced the overall rate of perioperative cardiovascular complications for elective hip or knee arthroplasty.

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ip and knee arthroplasties are performed on over 250,000 patients aged 65 years and older in the United States each year [1]. Comorbid conditions, which exist in the majority of these patients, place them at increased risk of cardiac complications in the perioperative period. Subclinical cardiac ischemia, which occurs in 31% to 33% of patients who undergo lower extremity arthroplasty, is a risk factor for short- and long-term cardiac morbidity and mortality [2–4]. Myocardial infarction occurs in 0.4% of patients who undergo hip or knee arthroplasty and is associated with a 17% to 42% mortality rate [5–8]. Efforts to identify patients at increased risk of postoperative myocardial infarction has led to the development of risk prediction tools, which permit interventions to reduce perioperative cardiac risk [9,10].

This risk of myocardial infarction can be reduced by using β-adrenergic blocking agents (β blockers) in high-risk patients who undergo noncardiac surgery [11–13]. β Blockers have also been shown by Urban and colleagues to reduce electrocardiographic evidence of myocardial ischemia after knee arthroplasty from 14% to 4%, and are suggested for patients at risk for postoperative cardiac complications in the American College of Cardiology/American Heart Association (ACC/AHA) guidelines for perioperative cardiovascular evaluation for noncardiac surgery [10,14].

Despite this evidence, β blockers are used in only 27% to 54% of surgical patients at high risk for cardiac complications, and only 9% to 10% of surveyed hospitals have pathways in place to increase perioperative β-blocker use [15–19]. Surveys indicate that controversy exists regarding patient selection, timing, duration, and efficacy of perioperative β-blocker therapy [14,16,20]. These uncertainties, as well as practical concerns such as which physician will be responsible for the management of β-blocker therapy, contribute to the underutilization of this intervention [14]. Improved perioperative β-blocker utilization has been demonstrated in 2 cohort studies using a clinical pathway to identify high-risk surgical patients who may benefit from perioperative β-blocker therapy [21,22].

We hypothesized that the implementation of a hospital-wide operative risk management pathway would increase utilization of perioperative β-blockers and also lead to reductions in cardiac complications of elective hip and knee arthroplasty.
Methods

Setting
This before and after intervention cohort study was conducted at Memorial Medical Center (Springfield, IL), a 562-bed tertiary care center affiliated with Southern Illinois University School of Medicine as part of a hospital-wide quality improvement effort. The study protocol was approved by the local institutional review board, and informed consent for data collection was waived.

Risk Management Pathway Development
We developed an operative risk management pathway (Figure) with the input of representatives from many disciplines, including internal medicine, surgery, anesthesiology, cardiology, pharmacy, nursing, and hospital administration. After development was complete, a hospital-wide education process prepared departments for the use of this pathway for all hip and knee arthroplasties beginning 15 September 2003.

This risk assessment pathway incorporates elements of the Revised Cardiac Risk Index [9] and predictors of cardiac risk from Mangano [4] (Table 1). Hip or knee arthroplasty is considered to be an intermediate-risk surgery [10]. Patients were considered β-blocker candidates if they had 1 or more major predictors of cardiac risk or 2 or more minor predictors of cardiac risk.

The outpatient risk assessment form was provided in print format and as an Adobe Acrobat PDF (Adobe Inc., San Jose, CA) file downloadable from the Southern Illinois University School of Medicine Web site. The current version of the risk assessment form is available at www.siumed.edu/
medicine/DGIM/PreOperativeAssessment.pdf. (Since the completion of this study, the minor risk factors were expanded to include obesity and impaired glucose tolerance.)

Outpatient risk assessment was voluntary and was intended to supplement the ACC/AHA guidelines for perioperative cardiovascular evaluation for noncardiac surgery by assisting in the identification of patients who had the potential to benefit from perioperative β-blocker therapy. The inpatient risk assessment was mandatory, and the initiation of β-blocker therapy was suggested for all eligible patients to the treating physician(s).

Prior to the development of this pathway, no hospital-wide strategies were in place to assess and modify perioperative cardiac risk. Perioperative monitoring, surgical techniques, evaluation for cardiac complications, and other therapies were left to the treating physicians in the pre- and postintervention phases of the study.

Alternative therapies with the potential to attenuate the cardiac risks of surgery, such as α₂ agonists, were not promoted in this pathway.

**Patient Selection and Data Collection**

Charts from 300 consecutive patients admitted for elective unilateral primary total hip or knee arthroplasty during the preintervention (1 September 2002 to 21 February 2003) and postintervention (15 September 2003 to 22 February 2004) phases were reviewed. No patients were contacted for the purposes of this study, no patient identifiers were recorded, and no postdischarge follow-up data were available for review.

After patient discharge, medical records were reviewed to collect data on demographic characteristics, type of arthroplasty performed (hip or knee), complications of the surgery, length of hospital stay, β-blocker use, and chronic medical conditions included in the major and minor predictors of cardiac risk. Risk factors that were not clearly documented were assumed to be not present for the purpose of determining if a patient was a β-blocker candidate. Data regarding perioperative aspirin, statin, angiotensin-converting enzyme inhibitor, or angiotensin receptor blocker use was not extracted.

Data extraction was done by several of the authors (RLR, JMA, and SH), and accurate data entry was confirmed by comparison of numbered data gathering sheets to the database.

**Definitions**

β-Blocker candidates were defined as those patients meeting the criteria for β-blocker therapy.

Myocardial infarction was defined as documentation of diagnostic elevations of biochemical markers of myocardial necrosis (troponin I or creatine kinase, myocardial bound) and ischemic symptoms or the development of new pathologic Q waves.

Unstable angina was defined as a documentation of a clinical syndrome consistent with ischemic chest pain prompting an investigation into the etiology of the chest pain that did not meet criteria for myocardial infarction.

Congestive heart failure (CHF) was defined as documentation of clinical evidence (rales or S₃ or S₄), radiographic evidence (pulmonary edema on chest radiography), brain natriuretic peptide, or echocardiographic findings characteristic of CHF.

Significant arrhythmia was defined as documentation of acute onset of atrial fibrillation, atrial flutter, ventricular tachycardia, second-degree heart block, or third-degree heart block.

Cardiac ischemia was defined as either myocardial infarction or angina.

Cardiac complications was defined as either myocardial infarction, angina, CHF, or significant arrhythmia.

**Statistical Analysis**

Data were extracted from existing medical records to a piloted data gathering sheet, entered into Excel XP (Microsoft Corp., Redmond, WA), and exported to SPSS version 11.5 (SPSS Inc., Chicago, IL) for analysis.

Differences in pre- and postintervention patient characteristics were assessed with the use of chi-square or Fisher’s exact test for categorical variables, and the t test for numerical values. All P values are 2-sided; a P value of less than or equal to 0.05 was considered statistically significant.

Based on other published studies, we estimated that 33% of patients scheduled for hip or knee arthroplasty would be β-blocker candidates and that our preintervention β-blocker utilization rate would be 20%. Power calculations indicated that pre- and postintervention group sizes of 91 or more β-blocker candidates would have greater than 80% power to detect an improvement of perioperative β-blocker use from

<table>
<thead>
<tr>
<th>Table 1. Major and Minor Predictors of Surgical Risk</th>
</tr>
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<tbody>
<tr>
<td><strong>Major predictors [9]</strong></td>
</tr>
<tr>
<td>Ischemic heart disease</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
</tr>
<tr>
<td>Diabetes</td>
</tr>
<tr>
<td>Serum creatinine ≥ 2 mg/dL (≥ 176.8 µmol/L)</td>
</tr>
<tr>
<td>Congestive heart failure</td>
</tr>
<tr>
<td>High-risk surgery*</td>
</tr>
<tr>
<td><strong>Minor predictors [4]</strong></td>
</tr>
<tr>
<td>Age ≥ 65 years</td>
</tr>
<tr>
<td>Hypercholesterolemia</td>
</tr>
<tr>
<td>Current smoker</td>
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<tr>
<td>Hypertension</td>
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</tbody>
</table>

*Surgeries defined as high-risk in Table 3 of ACC/AHA perioperative cardiovascular evaluation for noncardiac surgery [10].
20% to 40% between the groups using a 2-sided chi-square test with a significance level of 0.05 or less. Based on this information, we selected a preintervention sample size of 300 to assure adequate power to detect a significant difference in the 2 groups.

## Results
Data from 300 consecutive preintervention and 300 consecutive postintervention total hip and knee arthroplasty patients were gathered. All 300 postintervention patients completed the inpatient cardiac risk assessment process. Demographic and clinical characteristics of these groups are shown in Table 2. There is an increased proportion of patients with renal insufficiency (2% versus 6%; \( P = 0.004 \)), hyperlipidemia (1% versus 6%; \( P = 0.001 \)), and current smoking (2% versus 10%; \( P \leq 0.001 \)) in the postintervention group. More patients underwent general anesthesia in the preintervention group (80% versus 71%; \( P = 0.08 \)) or had diabetes (18% versus 13%; \( P = 0.20 \). However, these differences did not reach statistical significance.

Overall perioperative \( \beta \)-blocker use increased from 18% to 60% (\( P < 0.001 \), with a corresponding reduction in cardiovascular complications (11% versus 1.1%; \( P < 0.001 \)). The rates of cardiac ischemia (7% versus 1%; \( P < 0.001 \), myocardial infarction (3% versus 1%; \( P = 0.038 \), angina (4% versus 1%; \( P = 0.002 \), and CHF (4% versus 0%; \( P < 0.001 \) were reduced in the postintervention group. No significant reduction in the rate of arrhythmia was found (2% versus 1%; \( P = 0.068 \)). No deaths occurred in either group, and the hospital length of stay was reduced in the postintervention group (3.35 days versus 3.9 days; \( P = 0.005 \)).

The postintervention group had an increased rate of \( \beta \)-blocker therapy started in the outpatient (18% versus 46%; \( P < 0.001 \) and inpatient (0% versus 15%; \( P < 0.001 \) settings. Complications of \( \beta \)-blocker therapy were documented in 6 (2%) postintervention patients (0% versus 2%; \( P = 0.03 \). Symptomatic bradycardia was documented in 2 patients, and symptomatic hypotension was documented in 4 patients. The next postsymptom \( \beta \)-blocker dose was withheld for the 6 patients who experienced \( \beta \)-blocker-related adverse events.

Among the patients identified as \( \beta \)-blocker candidates (Table 4), perioperative \( \beta \)-blocker use increased from 25% to 85% (\( P < 0.001 \). Cardiovascular complications were reduced from 12% to 2% (\( P < 0.001 \). The rates of cardiac ischemia (9%
versus 1%; \( P = 0.001 \), angina (5% versus 1%; \( P = 0.009 \)), and CHF (3% versus 0%; \( P = 0.003 \)) were reduced in the postintervention group. The rate of myocardial infarction was reduced in a manner that showed a trend towards statistical significance (4% versus 1%; \( P = 0.06 \)). The rate of arrhythmia (4% versus 1%; \( P = 0.204 \)) or hospital length of stay (4.03 days versus 3.8 days; \( P = 0.126 \)) did not differ between the 2 groups.

**Discussion**

This study shows that an operative risk management pathway promoting the use of perioperative \( \beta \)-blockers was effective for increasing appropriate utilization of perioperative \( \beta \)-blockers (25% to 85%; \( P < 0.001 \)) and reduces the overall rate of nonfatal cardiovascular complications (12% to 2%; \( P < 0.001 \)) for elective hip or knee arthroplasty. Although no cardiac deaths occurred in the pre- or postintervention groups, the incidence of nonfatal myocardial infarction, angina, and CHF declined after implementation of this pathway. The high rate of perioperative \( \beta \)-blocker utilization is likely a result of screening for \( \beta \)-blocker candidates in outpatient clinic during preoperative risk assessment and in the preanesthesia unit 3 days prior to surgery. This process reduced fragmentation in the pre- and postoperative management of patients with the cooperation of hospital personnel, anesthesiologists, surgeons, and primary care physicians to reduce postoperative cardiac complications.

Perioperative \( \beta \)-blocker investigations have concentrated on vascular surgeries or heterogeneous populations that included small proportions of orthopaedic surgeries [11,12]. This investigation focuses on hip and knee arthroplasties, which are performed on over 250,000 older patients per year in the United States [1]. The nonurgent nature of most hip or knee arthroplasties and the large number of procedures make these surgeries ideal targets to develop and refine pathways to assess and reduce cardiac risks of noncardiac surgeries. We found a 3% rate of myocardial infarction in the preintervention phase of the study, consistent with the classification of arthroplasties as intermediate-risk surgeries.

The 3% rate of myocardial infarction in the preintervention phase of study is much higher than the 0.4% rate reported by Mantilla and colleagues, likely reflecting our expanded definition of myocardial infarction that includes non–ST segment elevation myocardial infarction [5]. The rate of significant arrhythmias (3%) is similar to the 3.1% rate reported by Kahn and colleagues [23].

Implementation of this simple clinical pathway resulted in a significant increase in appropriate perioperative \( \beta \)-blocker therapy (25% versus 85%), corresponding reductions in cardiac events (12% versus 2%), and a modest decrease in hospital length of stay (3.9 versus 3.55 days). These factors may contribute to reduced health care costs, and data from models estimating hospital costs for \( \beta \)-blocker therapy before major surgery predict hospital cost savings of $500 to $658 per patient treated with a \( \beta \)-blocker [16,24]. Using these estimates, the use of \( \beta \)-blocker therapy in 157 of the 183 postintervention \( \beta \)-blocker candidates has the potential for $78,500 to $103,306 in hospital cost savings over the study period. In addition to potential cost savings, the reductions in postoperative cardiac ischemic events is likely to result in long-term reductions in cardiac mortality for patients treated with \( \beta \) blockers.

Implementation of a clinical pathway designed to increase drug use is not without risk. \( \beta \)-blocking agents can cause adverse events such as bradycardia, bronchospasm, and hypotension. A systematic review of perioperative \( \beta \)-blocker trials indicated that bradycardia was the most common adverse event and occurred in 24.5% of patients [24], which is higher than the 2% rate of adverse events attributed to \( \beta \) blockers in our study. This difference may be due to the lack of a mandatory \( \beta \)-blocker dose titration process, which would increase the risk of bradycardia and hypotension. Withdrawal of acute perioperative \( \beta \) blockade, which may occur after hospital discharge if a new \( \beta \)-blocker prescription was not filled, is associated with an increased risk of cardiac events [25]. These potential cardiac events would not be detected by this study.

This study has limitations. This study was a retrospective, **Table 4. Cardiovascular Complications and \( \beta \)-Blocker Utilization in \( \beta \)-Blocker Candidates**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Preintervention (n = 173)</th>
<th>Postintervention (n = 183)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any cardiovascular complication, n (%)</td>
<td>20 (12)</td>
<td>3 (2)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Cardiac ischemia</td>
<td>15 (9)</td>
<td>2 (1)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>6 (4)</td>
<td>1 (1)</td>
<td>0.061</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>9 (5)</td>
<td>1 (1)</td>
<td>0.009*</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>8 (5)</td>
<td>0</td>
<td>0.003*</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>4 (2)</td>
<td>1 (1)</td>
<td>0.204</td>
</tr>
<tr>
<td>Death</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total perioperative ( \beta )-blocker therapy, n (%)</td>
<td>44 (25)</td>
<td>157 (86)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>( \beta ) Blocker started as outpatient</td>
<td>44 (25)</td>
<td>118 (64)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>( \beta ) Blocker started as inpatient</td>
<td>0</td>
<td>39 (21)</td>
<td>&lt; 0.001*</td>
</tr>
<tr>
<td>Length of hospital stay (SD)</td>
<td>4.03 (1.3)</td>
<td>3.8 (2)</td>
<td>0.126</td>
</tr>
</tbody>
</table>

Note: Patients could have more than 1 cardiac complication.

*\( P \leq 0.05 \).
nonrandomized, single center cohort study with a short (approximately 4 days in hospital) follow-up period. There was an increased proportion of patients with renal insufficiency (2% versus 6%), hyperlipidemia (1% versus 6%), and current smoking (2% versus 10%) in the postintervention group. The differing rates of smoking, hyperlipidemia, and renal insufficiency may reflect more thorough risk factor documentation in the postintervention patients and not actual differences between the populations.

Additionally, more patients underwent general anesthesia in the preintervention group (80% versus 71%), which does not appear to influence the rate of cardiac ischemia in patients who undergo hip arthroplasty [26]. More patients had diabetes (18% versus 13%) in the preintervention group, which is clearly a risk factor for coronary artery disease. However, these differences did not reach statistical significance.

Studies with larger populations, long-term follow-up, multiple centers, and other types of surgeries would be useful to clarify the impact this risk management pathway has on surgical outcomes and health care costs. Efforts are underway to expand the use of this risk management pathway to a broader surgical population. However, this study demonstrates that the use of a preoperative clinical risk management pathway to promote perioperative β-blocker use can increase the rate of perioperative β-blocker utilization and decrease the rate of nonfatal perioperative cardiovascular complications.

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Financial disclosures: None.

Author contributions: conception and design, RLR, JMA, SH, RB, RV; analysis and interpretation of data, RLR; drafting of the article, RLR; critical revision of the article, RLR, JMA, SH, RB, RV; statistical expertise, RLR; administrative support, RB, RV; collection and assembly of data, RLR, JMA, SH.

References


