Multimodal Pain Management With Adductor Canal Block Decreases Opioid Consumption Following Total Knee Arthroplasty

Neil Thomas Soehnlen, MD; Eric Donald Erb, MD; Eric McKee Kiskaddon, MD; Uthona Green, DNP; Andrew Froehle, PhD; and Anil Krishnamurthy, MBBS

Background: Ease of access to opioids in the perioperative period is a risk factor for subsequent opioid misuse. The purpose of this study was to quantify a decrease in opioid consumption following implementation of a new analgesic protocol after total knee arthroplasty (TKA).

Methods: A retrospective cohort study was performed analyzing patients who underwent TKA at a US Department of Veterans Affairs medical center. Patients were divided into 2 groups by multimodal analgesic regimen: Analgesia with intraoperative general anesthesia, a patient-controlled analgesia pump, and oral opioids (control group) or analgesia with intraoperative spinal anesthesia, a multimodal medication regimen, and an adductor canal block (protocol group).

Results: A total of 533 TKAs were included. The mean (SD) IV morphine equivalent dose (MED) requirement was 178.2 (98.0) for the control and 12.0 (24.6) for the protocol group (P < .001). Total mean (SD) opioid MED requirement was 241.7 (120.1) for the control group and 74.8 (42.7) for the protocol group (P < .001). The protocol group required only 6.7% of the IV opioids and the control group 30.9%. No difference in oral opioid requirements was found (P = .85). The control group required more opioid refills at the first postoperative visit (P < .001).

Conclusions: The described analgesic protocol resulted in significant decreases in IV and total opioid requirement, and lower rates of opioid prescriptions at the first postoperative visit. These findings demonstrate a decrease in opioid utilization with modern perioperative analgesia protocols and reinforce multiple recommendations to decrease opioid exposure and access.
effect of opioid consumption on range of motion on postoperative day (POD) 1 and number of opioid prescriptions written at the first postoperative clinic visit.

**METHODS**

Approval for the study was obtained from the institutional review board at the Dayton Veterans Affairs Medical Center (DVAMC) in Ohio. A retrospective chart review was performed to collect data from all patients undergoing TKA at DVAMC from June 1, 2011, through December 31, 2015. Exclusion criteria included multiple surgeries in the study time frame, documented chronic pain, allergy to local anesthetics, daily preoperative use of opioids, and incomplete data in the health record.

All surgeries were performed by 2 staff arthroplasty surgeons at a single VAMC. All patients attended a preoperative visit where a history, physical, and anesthesia evaluation were performed, and watched an educational video detailing surgical indications and postoperative rehabilitation. All surgeries were performed with tourniquets and a periarticular injection was performed at the conclusion of each case. Surgeon 1 treatment of choice was 10 mL 0.5% bupivacaine, whereas surgeon 2 performed a posterior capsular injection of 30 mL 0.25% bupivacaine and a periarticular injection of 30 mg ketorolac in 10 mL 0.25% bupivacaine with epinephrine.

Prior to August 2014, general endotracheal anesthesia was used intraoperatively. A patient-controlled analgesia (PCA) pump of morphine or hydromorphone and additional oral oxycodone or hydrocodone was used for postoperative pain. PCA pumps were patient dependent. In the control group, 245 patients received the morphine PCA while 61 received the hydromorphone PCA. Morphone PCA dosing consisted of 1-mg doses every 10 minutes with potential baseline infusion rates of 0.5 to 1.0 mg/h and a 4-hour limit of 20 mg. Hydromorphone PCA dosing consisted of 0.2 to 0.4-mg doses with a potential continuous dose of 0.2 to 0.4 mg/h and a 4-hour limit of 4 mg.

In August 2014, a new analgesic protocol was adopted for TKA consisting of intraoperative spinal anesthesia (0.75% bupivacaine) with IV sedation (propofol), a postoperative multimodal analgesic regimen, an ACB performed in the postanesthesia care unit (PACU), and opioids as needed (protocol group). The ACB catheter was a 0.5% ropivacaine hydrochloride injection. It was attached to a local anesthetic fixed flow rate pump that administers 0.5% ropivacaine without epinephrine at 8 mL/h and was removed on POD 5 by the patient. The multimodal medication regimen included IV ketorolac 15 mg every 6 hours for 3 doses, gabapentin 300 mg every 8 hours, acetaminophen 975 mg every 8 hours, meloxicam 7.5 mg daily, tramadol 50 mg every 6 hours, oxycodone 5 mg 1 to 2 tabs every 4 hours as needed, and IV hydromorphone 0.5 mg every 4 hours as needed for breakthrough pain.

Preoperative demographic characteristics were collected (Table 1). Data on all IV and oral opioid requirements were collected for both groups, converted to morphine milligram equivalents (MME), and a total morphine equivalent dose (MED) was calculated.\(^20,21\)

In April 2015, a separate protocol change occurred at the DVAMC with the goal of discharge on POD 1. To standardize outcomes before and after this change, data collection regarding opioid requirements was concluded at midnight on POD 1.

<table>
<thead>
<tr>
<th>TABLE 1 Preoperative Demographic Characteristics</th>
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<tbody>
<tr>
<td>Variables</td>
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<tr>
<td>------------</td>
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<tr>
<td>Age, mean (SD), y</td>
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<tr>
<td>Sex, male/female, %</td>
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<tr>
<td>Body mass index, mean (SD)</td>
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<tr>
<td>Range of motion.* (SD)</td>
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<tr>
<td>Maximum knee extension</td>
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<tr>
<td>Knee total arc</td>
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<tr>
<td>Comorbid conditions, %</td>
</tr>
<tr>
<td>Diabetes mellitus type 1</td>
</tr>
<tr>
<td>Diabetes mellitus type 2</td>
</tr>
<tr>
<td>Coronary artery disease</td>
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<tr>
<td>Chronic obstructive pulmonary disease</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
</tr>
<tr>
<td>Deep vein thrombosis history</td>
</tr>
<tr>
<td>Pulmonary embolism history</td>
</tr>
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<td>Preoperative emergency department visits, mean (SD)</td>
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</tbody>
</table>

*Between-groups differences using independent samples using t tests for continuous data and Fisher exact tests for discrete data.
TABLE 2 Perioperative Characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Control (n = 306)</th>
<th>Protocol (n = 227)</th>
<th>P value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgeon 1/2, %</td>
<td>55.6/44.4</td>
<td>52.4/47.6</td>
<td>.48</td>
</tr>
<tr>
<td>Tourniquet time, mean (SD)</td>
<td>68.1 (13.8)</td>
<td>69.8 (12.4)</td>
<td>.13</td>
</tr>
<tr>
<td>Length of stay, mean (SD), d</td>
<td>2.5 (1.3)</td>
<td>1.4 (0.7)</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

*Between-groups differences using independent samples using t tests for continuous data and Fisher exact tests for discrete data.

RESULTS

During the study period from June 1, 2011, through December 31, 2015, 533 eligible TKAs were performed, 306 in the control group and 227 in the protocol group. The groups had similar sex distribution; body mass index; knee range of motion; diagnoses of diabetes mellitus, coronary artery disease, and chronic kidney disease; and history of deep vein thrombosis (DVT) or pulmonary embolism (P ≥ .05). The protocol group was significantly older (P = .04) and had a significantly higher rate of chronic obstructive pulmonary disease (COPD) (P = .002). There were no significant differences between number of procedures performed by surgeon (P = .48) or total tourniquet time (P = .13) (Table 2). Mean (SD) length of stay was significantly greater in the control group compared with the protocol group (2.5 [1.3] vs 1.4 [0.7] days, P < .001).

Figure 1 shows the distributions of each type of opioid used. Compared with the control group, the protocol group had a significantly lower mean (SD) IV opioid use: 178.2 (98.0) MED vs 12.0 (24.6) MED (P < .001; d = 2.19; Δ = 0.94) and mean (SD) total opioid use: 241.7 (120.1) MED vs 74.8 (42.7) MED (P < .001; d = 1.76; Δ = 0.89). Mean (SD) oral opioid use did not differ between groups (control, 63.6 [45.4] MED; protocol, 62.9 [31.4] MED; P = .85; d = 0.02; Δ = 0.51). A significantly lower percentage of patients in the protocol group received additional opioids at the 3-week follow-up when compared to the control group: 46.7% vs 61.3%, respectively (P < .001; RR, 0.76; 95% CI, 0.65-0.90).

There were no significant differences in postoperative mean (SD) maximum knee flexion (control, 67.2 [15.7]°; protocol, 67.8 [19.2]°; P = .72; d = 0.03; Δ = 0.51) or mean (SD) total flexion/extension arc (control, 66.2 [15.9]°; protocol, 67.9 [19.4]°; P = .32; d = 0.10; Δ = 0.53). Mean (SD) postoperative maximum knee extension was significantly higher in the protocol group compared with the control group (-0.1 [2.1]° vs 1.0 [3.7]°; P < .001; d = 0.35; Δ = 0.60). More patients in the protocol group (92.5%) were discharged to home compared with the control group (86.6%) (P = .02; RR, 1.07; 95% CI, 1.01-1.13).

Because age and rates of COPD differed between groups, sensitivity analyses were conducted to determine whether these variables influenced postoperative opioid use. The relationship between age and group was significant for IV (P < .001) and total opioid use (P < .001). Younger patients received higher MED doses than older patients within the control group, while dosages were fairly consistent regardless of age in the protocol group.
age in the protocol group (Figure 2). There was no significance in age interaction effect with regard to oral opioids \( (P = .83) \) nor opioid refills at 3-week follow-up \( (P = .24) \).

The sensitivity analysis for COPD found that a diagnosis of COPD did not significantly influence utilization of IV opioids \( (P = .10) \), or total opioids \( (P = .68) \). There was a significant interaction effect for oral opioids (Figure 3). Patients in the control group with COPD required significantly higher mean \( (SD) \) oral opioids than patients without COPD \( 91.5 \ [123.9] \ MED \) and \( 62.0 \ [36.0] \ MED \), respectively; \( P = .03 \). In the control group, the \( \chi^2 \) test was significant regarding opioid prescription refills at the 3-week visit \( (P = .004) \) with 62.4\% of patients with COPD requiring refills vs 44.4\% without COPD \( (P = .004) \). There was no difference in refills in the protocol group \( (46.4\% \ vs \ 48.4\%) \).

Finally, 2-sided independent samples \( t \) test evaluated total MED use between the 2 surgeons. There was no difference in total MED per patient for the surgeons. In the control group, mean \( (SD) \) total MED for surgeon 1 was \( 232.9 \ [118.7] \ MED \) vs \( 252.8 \ [121.5] \ MED \) for surgeon 2 \( (P = .18) \). In the protocol group, the mean \( (SD) \) total MED was \( 72.5 \ [43.2] \) and \( 77.4 \ [42.1] \) for surgeon 1 and surgeon 2, respectively \( (P = .39) \).

**DISCUSSION**

Coordinated efforts with major medical organizations are being made to decrease opioid prescriptions and exposure.\(^5\)\(^6\) To our knowledge, no study has quantified a decrease in opioid requirement in a VA population after implementation of a protocol that includes intraoperative spinal anesthesia and a postoperative multimodal analgesic regimen including ACB after TKA. The analgesic protocol described in this study aligns with recommendations from both
the CDC and the AAOS to decrease opioid use and misuse by maximizing nonopioid medications and limiting the size and number of opioid prescriptions. However, public and medical opinion of opioids as well as prescribing practices have changed over time with a trend toward lower opioid use. The interventions, as part of the described protocol, are a result of these changes and attempt to minimize opioid use while maximizing postoperative analgesia.

Our data showed a significant decrease in total opioid use through POD 1, IV opioid use, and opioid prescriptions provided at the first postoperative visit. The protocol group used only 6.7% of the IV opioids and 30.9% of the total opioids that were used by the control group. The substantial difference in IV opioid requirement, 166.2 MED, is equivalent to 8 mg of IV hydromorphone or 55 mg of IV morphine. The difference in total opioid requirement was similar at 166.9 MED, equivalent to 111 mg of oral oxycodone.

Decreasing opioid use has the additional benefit of improving outcomes, as higher doses of opioids have been associated with increased length of stay, greater rates of DVT, and postoperative infection. These complications occurred in a stepwise manner, suggesting a dose-response gradient that makes the sizable decrease noted in our data of greater relevance. While the adverse effects (AEs) of opioids are well known, there are limited data on opioid dosing and its effect on perioperative outcomes.

A significant decrease in the percentage of patients receiving an opioid prescription at the first postoperative visit suggests a decrease in the number of patients on prolonged opioids after TKA with implementation of modern analgesic modalities. The duration of postoperative opioid use has been found to be the strongest predictor of misuse, and each postoperative refill increases the probability of misuse by 44%. In addition, opioid use for > 3 months after TKA is associated with increased risk of periprosthetic infection, increased overall revision rate, and stiffness at 1 year postoperatively. While not entirely under the control of the surgeon, measures to decrease the number of postoperative opioid refills may lead to a decrease in opioid misuse.

In the control group, older patients tended to receive less opioids. This is likely due to physiologic changes in opioid metabolism associated with aging, including decreased renal and hepatic opioid metabolism and alterations in overall body composition that increase relative potency and duration of action of opioids in a geriatric population. No difference in opioid use by age was found for the protocol group.

Patients in the protocol group demonstrated significantly greater maximal knee extension on POD 1 compared with the control group. No difference in maximal flexion was found. This difference in extension may
partially be explained by the use of an ACB. One benefit of ACB is greater quadriceps strength and fewer near-fall events when compared with FNB. Our results corroborate the findings of similar studies. A randomized controlled trial comparing a multimodal analgesic regimen with a periarticular injection without a postoperative ACB to a hydromorphone PCA revealed a significant decrease in opioid use in the multimodal analgesic group. Along with lower opioid requirements, the multimodal analgesic group had lower visual analog scale pain scores, fewer AEs, faster progression to physical therapy milestones, and higher satisfaction. Recent guidelines from the French Society of Anaesthesia and Intensive Care Medicine recommend against the use of gabapentin as a method of postoperative pain control. However, this specifically refers to the preoperative administration of gabapentin. This same set of guidelines later cites a high level of evidence suggesting patients undergoing arthroplasty benefit more from gabapentinoids. Multiple analgesic protocols that include gabapentin as a part of a multimodal approach have been shown to have positive results.

In our study, patients receiving the multimodal analgesic regimen were significantly more likely to be discharged home rather than to postacute care facilities, which have been associated with increased rates of major complications, 30-day readmission, and 30-day reoperation. In addition, discharge to an inpatient rehabilitation or skilled nursing facility has not been found to result in higher functional outcomes, despite $3.2 billion spent yearly on rehabilitation services after primary TKA.

A component of our described analgesic protocol included spinal anesthesia intraoperatively. The differences between groups regarding anesthesia type can be attributed to this protocol change. A significantly greater percentage of patients in the protocol group received spinal anesthesia, while more patients in the control group received general anesthesia. While patients who received spinal anesthesia may have enhanced analgesia in the immediate postoperative period, no differences in opioid outcomes were seen based on anesthesia type. Known benefits of intraoperative spinal anesthesia include decreased perioperative blood loss and a smaller decrease in hemoglobin postoperatively, as well as lower rates of in-hospital complications, including pulmonary embolism, pneumonia, cerebrovascular events, and acute renal failure.

Limitations
A number of limitations of this study should be noted. One was a protocol change regarding length of stay, which occurred during the study period and resulted in a significantly shorter length of stay in the protocol group. As a result, opioid

**FIGURE 3 Interaction Effect of COPD and Group on Opioid Use**

Abbreviation: COPD, chronic obstructive pulmonary disease.
use data were analyzed only through midnight at the end of POD 1. Patients who were discharged on POD 1 did not have opioid use data available for the full duration of the first POD, which may exaggerate the decrease in opioid requirements, as opioids used after discharge but prior to midnight on POD 1 were not recorded. However, opioids taken at home are oral with a low MME compared with IV opioids received by hospitalized patients in the control group. In addition, if taken as prescribed, patients at home would only have enough time to take a few doses of opioids prior to the midnight cutoff. We do not believe this difference in time of opioid use meaningfully affected the data. An additional limitation includes the variability between periarticular injections between surgeons. While the percentage of patients that received injections from surgeon 1 vs surgeon 2 were similar, it cannot be ruled out as a potential confounding factor. Other limitations include a lack of pain scores to compare subjective pain ratings, the retrospective nature of the study, and a largely homogenous male VA population.

CONCLUSIONS
Ease of access to opioids is a risk factor for opioid abuse, which itself is a risk factor for subsequent heroin use.12 The CDC and AAOS have thus published recommendations regarding opioid prescribing practices to decrease opioid use and abuse.5,6 Our described protocol, which aligns with these recommendations, resulted in a significant decrease in IV opioid requirement, total opioid requirement, and lower rates of opioid prescriptions provided at the first postoperative visit. These promising findings demonstrate a lower percentage of patients on long-term opioids after TKA and a significantly decreased cumulative opioid exposure.

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Ethics and consent
This article does not contain any studies with human participants or animals performed by any of the authors. Full institutional review board approval for human data was obtained through both Wright State University as well as the Dayton Veterans Affairs Medical Center institutional review boards. Informed consent was not required for this consent-exempt study.

References
Knee Arthroplasty Pain

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