A Multimodal Pain Management Regimen Utilizing Adductor Canal Block in a Veterans Affairs Population Decreases Opioid Consumption Following Total Knee Arthroplasty.

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Abstract

Background: Ease of access to opioids in the perioperative period is a risk factor for subsequent opioid abuse. 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 Veterans Affairs medical center. Patients were divided into two groups by multimodal analgesic regimen: Analgesia with intraoperative general anesthesia, a patient controlled analgesia pump, and oral opioids (Traditional 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 intravenous morphine equivalent dose (MED) requirement was 178.2 ± 98.0 for Traditional and 12.0 ± 24.6 for Protocol groups ($p < 0.001$). Total opioid MED requirement was 241.7 ± 120.1 for Traditional and 74.8 ± 42.7 in Protocol groups ($p < 0.001$). The Protocol group required only 6.7% of the intravenous opioids and 30.9% of the total opioids used by the Traditional group. No difference in oral opioid requirements was found ($p = 0.849$). The Traditional group required more opioid refills at the first postoperative visit ($p < 0.001$).

Conclusions: The described analgesic protocol resulted in significant decreases in intravenous 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 recommendations by the CDC and AAOS to decrease opioid exposure and access.

Trial Registration: Not applicable

Background

Ease of access to opioids in the perioperative period is a risk factor for opioid abuse [1] and has been identified as a strong risk factor for heroin use [2]. 75% of today's heroin users were introduced to opioids through prescription medications [2]. The United States accounts for roughly 80% of the global opioid supply consumption and deaths from opioid overdose are increasing, with 63,000 deaths in 2016 alone [3, 4]. The Centers for Disease Control and Prevention (CDC) has called for changes in opioid prescribing. The American Academy of Orthopaedic Surgeons (AAOS) has also published an information statement with strategies to decrease opioid misuse and abuse [5, 6]. Arthroplasty surgeons have recently focused on decreasing utilization of opioids in total knee arthroplasty (TKA), a procedure traditionally associated with high levels of opioid consumption [7], and historical reliance on opioid monotherapy for postoperative analgesia [8]. From a clinical perspective, prolonged postoperative opioid use contributes to poorer surgical outcomes due to increased risk of complications including stiffness, infection, and revision TKA [9].

Peripheral nerve blocks, such as adductor canal block (ACB) and femoral nerve block (FNB), have been utilized to decrease postoperative pain [10]. Studies have shown the ACB has less complications and shorter times to functional recovery when compared to FNB [11, 12]. The distribution of the ACB excludes the femoral nerve, thus preserving greater quadriceps strength while providing equivalent levels of analgesia compared to the FNB [11, 13, 14]. The ACB has shown decreased near-fall events and improved balance scores in the immediate postoperative period [15].

The present study analyzed opioid consumption patterns of TKA patients from a Veterans Affairs (VA) Medical Center before and after the institution of a multimodal analgesic protocol utilizing ACB. The primary purpose of this study was to determine whether a protocol including intraoperative spinal anesthesia with a postoperative multimodal analgesic regimen and ACB was associated with a decreased postoperative opioid requirement when compared to patients who received intraoperative general anesthesia and a traditional opioid regimen. Secondary outcomes included the 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 local institutional review board. A retrospective chart review was performed to collect data from all patients undergoing TKA at our VA Medical Center from June 1, 2011 through December 31, 2015. Exclusion criteria included multiple surgeries in the study time frame, chronic pain as documented in the medical record, allergy to local anesthetics, daily preoperative use of opioids, and incomplete data in the medical record.

All surgeries were performed by two staff arthroplasty surgeons at a single VA Medical Center. All patients attended a preoperative visit where a history, physical, and anesthesia evaluation was performed, and watched an educational video detailing surgical indications and postoperative rehabilitation. All surgeries were performed with a tourniquet and a periarticular injection was performed at the conclusion of each case. Surgeon One's injection of choice is 10 milliliters (mL) 0.5% bupivacaine, while Surgeon Two performs a posterior capsular injection of 30 mL 0.25% bupivacaine and a periarticular injection of 30 milligrams (mg) of ketorolac in 10 mL 0.25% bupivacaine with epinephrine.

Prior to August 2014, general endotracheal anesthesia was used intraoperatively. Postoperative pain control was obtained utilizing a patient controlled analgesia (PCA) pump of morphine or hydromorphone and additional oral oxycodone or hydrocodone (Traditional Group). In August 2014, a new analgesic protocol was adopted for TKA consisting of intraoperative spinal anesthesia with intravenous sedation, a postoperative multimodal analgesic regimen, an ACB performed in the post-anesthesia care unit (PACU), and opioids as needed (Protocol Group). The ACB catheter, attached to a local anesthetic fixed flow rate pump that administers 0.5% bupivacaine without epinephrine at 8 mL per hour, was removed on POD 5 by the patient. The multimodal medication regimen included intravenous ketorolac 15 mg every 6 hours for three 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 intravenous hydromorphone 0.5 mg every 4 hours as needed for breakthrough pain.

Preoperative demographic characteristics were collected to compare the groups and are listed in Table 1. Data on all intravenous and oral opioid requirements were collected, converted to milligram morphine equivalents (MME), and a total morphine equivalent dose (MED) was calculated [16, 17].

In April 2015, a separate protocol change occurred at our institution 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 POD1. If a patient was discharged before midnight on POD 1, opioid requirement through the time of discharge was collected. Patients were also evaluated by a physical therapist on POD 0, and maximal knee flexion and extension were measured on POD 1. Patients were discharged with prescriptions for oxycodone/acetaminophen and tramadol, and were then seen at three weeks for the first postoperative visit. The need for an opioid refill at the first postoperative visit was recorded.

All statistical analyses were performed in SAS 9.4 (Cary, NC) with significance set to $\alpha = 0.05$. Between-groups differences in preoperative and perioperative characteristics, as well as postoperative outcomes, were analyzed using independent samples t-tests for continuous variables, and Fisher's exact tests for dichotomous discrete variables. Where groups differed for a pre- or perioperative variable, linear mixed models analysis was used to determine whether intravenous, oral, and total MEDs were significantly affected by the interaction between the pre- or perioperative variable with analgesia group. For refills at the postoperative visit, the effects of pre- or perioperative differences were tested using chi-square tests. Effect sizes for outcome variables were estimated using Cohen's *d* and probability of superiority (Δ) for continuous variables [18], and relative risk ratios (RR) in the case of discrete variables.

Results

During the study period 533 eligible TKAs were performed; 306 in the Traditional group and 227 in the Protocol group. The groups did not differ significantly for sex distribution, BMI, knee range of motion, frequencies of diabetes mellitus (DM), coronary artery disease (CAD), chronic kidney disease (CKD), history of deep vein thrombosis (DVT) or pulmonary embolism (PE) (for each, $p \geq 0.052$, see Table 1). The Protocol group was significantly older ($p = 0.043$) and had a significantly higher rate of chronic obstructive pulmonary disease (COPD) ($p = 0.002$). Perioperative traits are in Table 2. There were no significant differences between number of procedures performed by surgeon ($p = 0.483$) or total tourniquet time ($p = 0.134$). Length of stay was significantly greater in the Traditional group compared to the Protocol group (2.5 ± 1.3 vs. 1.4 ± 0.7 days, $p < 0.001$).

Figure 1 shows the distributions of each type of opioid used. Compared to the Traditional group, the Protocol group had a significantly lower intravenous (IV) opioid requirement (178.2 ± 98.0 MED vs. 12.0 ± 24.6 MED, $p < 0.001$; $d = 2.19$; $\Delta = 0.94$) and total opioid requirement (241.7 ± 120.1 MED vs. 74.8 ± 42.7 MED, $p < 0.001$; $d = 1.76$; $\Delta = 0.89$). Oral opioid requirement did not differ between groups (Traditional:

63.6 ± 45.4 MED; Protocol: 62.9 ± 31.4 MED; $p = 0.849$; $d = 0.02$; Δ = 0.51). A significantly lower frequency of patients in the Protocol group required additional opioids at the three-week follow-up (46.7% vs. 61.3% in the Traditional group; $p < 0.001$; RR = 0.76; 95% confidence interval (CI) 0.65–0.90).

For secondary outcomes, there were no significant differences in postoperative maximum knee flexion (Traditional: 67.2 ± 15.7°; Protocol: 67.8 ± 19.2°; $p = 0.723$; $d = 0.03$; Δ = 0.51) or total flexion/extension arc (Traditional: 66.2 ± 15.9°; Protocol: 67.9 ± 19.4°; $p = 0.318$; $d = 0.10$; Δ = 0.53). Postoperative maximum knee extension was significantly higher in the Protocol group (-0.1 ± 2.1° vs. 1.0 ± 3.7°; $p < 0.001$; $d = 0.35$; Δ = 0.60). Patients in the Protocol group were more likely to be discharged to home (92.5% vs. 86.6%; $p = 0.020$; 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 had an effect on post-operative opioid utilization. The interaction between age and group was significant for IV ($p < 0.001$) and total opioid use ($p < 0.001$). Younger patients received more opioid doses than older patients within the Traditional group, while dosages were fairly consistent regardless of age within the Protocol group (Fig. 2). There was no significance in age interaction effect with regard to oral opioids ($p = 0.831$) nor opioid refills at 3-week follow-up ($p = 0.236$).

The sensitivity analysis for COPD found that a diagnosis of COPD did not significantly influence utilization of IV opioids ($p = 0.095$), or total opioids ($p = 0.682$). There was a significant interaction effect for oral opioids with patients in the Traditional group with COPD requiring significantly more oral opioids than patients without COPD (91.5 ± 123.9 MED and 62.0 ± 36.0 MED, respectively, $p = 0.028$; Fig. 3). In the Traditional group the chi-square test was significant regarding opioid prescription refills at the 3-week visit ($p = 0.004$) with 62.4% of patients with COPD requiring refills versus 44.4% without COPD (p = 0.004). There was no difference in refills in the Protocol group (46.4% vs 48.4%) (Fig. 3).

Finally, a two-sided independent samples t-test was performed to evaluate total MED utilization between the two surgeons. There was no difference in total MED per patient between Surgeon One and Surgeon Two with patients stratified to their respective groups. In the Traditional group, total MED for Surgeon One was 232.9 ± 118.7 MED versus Surgeon Two 252.8 ± 121.5 MED (p = 0.179). In the Protocol group, the total MED was 72.5 ± 43.2 and 77.4 ± 42.1(p = 0.393), for Surgeon One and Surgeon Two, respectively.

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 including intraoperative spinal anesthesia and a postoperative multimodal analgesic regimen including adductor canal block after TKA. The analgesic protocol described in this study aligns with recommendations from both the CDC and the AAOS to decrease opioid use and abuse by maximizing non-opioid medications and limiting the size and number of opioid prescriptions. However, it is important to note that public and medical opinion of opioids, as well as prescribing practices, have changed over time with a trend toward lower opioid utilization. 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 requirement through POD 1, IV opioid requirement, and opioid prescriptions provided at the first postoperative visit. The Protocol group required only 6.7% of the intravenous opioids and 30.9% of the total opioids required by the Traditional group. This substantial difference in intravenous opioid requirement, 166.2 MED, is equivalent to 8 mg of intravenous hydromorphone or 55 mg of intravenous 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 [19]. These complications occurred in a stepwise manner, suggesting a dose-response gradient that makes the sizable decrease noted in our data of greater relevance [19]. While the side effects of opioids are well known, there are limited data on opioid dosing and its effect on perioperative outcomes [19].

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% [20]. In addition, opioid use for greater than three months after TKA is associated with increased risk of periprosthetic infection, increased overall revision rate, and stiffness at one year postoperatively [9]. 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 Traditional group, older patients tended to receive less opioids. This is likely explained by physiologic changes in opioid metabolism associated with aging. These include decreased renal and hepatic opioid metabolism and alterations in overall body composition, which increase relative potency and duration of action of opioids in the elderly [21, 22]. No difference in opioid utilization by age was found for the Protocol group. This suggests that opioid utilization was at a level low enough that age differences in opioid metabolism did not result in a difference in opioid utilization.

Patients in the Protocol group demonstrated significantly greater maximal knee extension on POD 1 compared to the Traditional 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 less near fall events when compared to femoral nerve block [11, 15].

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 [24]. Along with lower opioid requirements, the multimodal analgesic group had lower visual analog scale

(VAS) pain scores, fewer adverse effects, faster progression to physical therapy milestones, and higher satisfaction [24].

In our study population, patients receiving the multimodal analgesic regimen were significantly more likely to discharge to home rather than a post acute care (PAC) facility. This is pertinent as discharge to PAC facilities has been associated with increased rates of major complications, 30 day readmission, and 30 day reoperation [25, 26]. 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 dollars being spent yearly on rehabilitation services after primary TKA [27, 28].

A unique aspect of our study is the continuation of the ACB catheter through the time of hospital discharge. The catheter is removed on POD 5 by the patient. Discharging with the ACB catheter allows the benefit of the local anesthetic to be continued through the fifth postoperative day and may result in decreased opioid use after discharge. This may play a role in the lower refill rates at the first postoperative clinic visit, but data on opioid use after discharge was unavailable in this study.

A component of our described analgesic protocol included spinal anesthesia intraoperatively. The differences between groups in regards to 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 Traditional 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 PE, pneumonia, cerebrovascular events, and acute renal failure [29].

One limitation was a protocol change regarding length of stay. This occurred during the study period and resulted in a significantly shorter length of stay in the Protocol group. Because of this, opioid use data were analyzed only through midnight at the end of POD 1. Patients who discharged on POD 1 did not have opioid use data available for the full duration of the first postoperative day. This difference may exaggerate the decrease in opioid requirements, as opioids used after discharge but prior to midnight on POD 1 were unable to be recorded. However, opioids taken at home are oral opioids with a low MME compared to intravenous opioids received by the Traditional group who remained hospitalized. 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 creates any meaningful effect on the data. Other limitations include a lack of pain scores to compare each group's subjective rating of pain, the retrospective nature of the study, and a largely homogenous male VA population.

Conclusion

Ease of access to opioids is a risk factor for opioid abuse, which itself is a risk factor for subsequent heroin use[1, 2]. 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.

Abbreviations

AAOS
American Academy of Orthopaedic Surgeons
ACB
Adductor canal block
CAD
Coronary artery disease
CDC
Centers for Disease Control
CI
Confidence interval
CKD
Chronic kidney disease
COPD
Chronic obstructive pulmonary disease
DM
Diabetes mellitus
DVT
Deep vein thrombosis
FNB
Femoral nerve block
IV
Intravenous
MED
Morphine Equivalent Dose
MME
Milligram morphine equivalents
PAC
Post acute care
PACU
Post-anesthesia care unit

PCA
Patient controlled analgesia
PE
Pulmonary embolism
POD
Post-operative day
RR
Relative risk
TKA
Total knee arthroplasty
VA
Veterans Affairs
VAS
Visual analog scale

Declarations

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Authors Contributions:

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Tables

Table 1. Preoperative Characteristics*							
Variable	Traditional (n=306)			Protocol (n=227)			*P*-value
Age (y)	63.5	±	8.6	65.0	±	8.1	0.043
Sex (% male)	91.2%			93.0%			0.522
BMI ($kg \bullet m^{-2}$)	31.5	±	4.9	32.2	±	4.0	0.090
Maximum knee flexion (°)	111.0	±	15.0	111.3	±	12.6	0.840
Maximum knee extension (°)	5.0	±	6.4	4.0	±	5.7	0.052
Knee total arc (°)	106.0	±	17.9	107.3	±	15.1	0.378
Type I diabetes (% yes)	2.6%			1.3%			0.368
Type II diabetes (% yes)	25.8%			32.2%			0.121
Cornary artery disease (% yes)	16.3%			19.8%			0.305
Chronic obstructive pulmonary disease (% yes)	5.9%			13.7%			0.002
Chronic kidney disease (% yes)	2.6%			3.5%			0.612
History of deep vein thrombosis (% yes)	2.0%			4.0%			0.192
History of pulmonary embolism (% yes)	1.3%			1.8%			0.728
Preoperative ED visits (visits per patient)	0.53	±	1.3	0.45	±	1.0	0.475
*Continuous data are presented as mean ± SD. P-values are for between-groups differences using independent samples t-tests (continuous data) or Fisher's exact tests (discrete data).							

Table 2. Perioperative characteristics*							
Variable	Traditional (n=306)			Protocol (n=227)			*P*-value
Surgeon	55.6%/44.4%			52.4%/47.6%			0.483
Tourniquet time (min)	68.1	±	13.8	69.8	±	12.4	0.134
Length of stay (days)	2.5	±	1.3	1.4	±	0.7	<0.001
*Continuous data are presented as mean ± SD. P-values are for between-groups differences using independent samples t-tests (continuous data) or Fisher's exact tests (discrete data).							

Figures

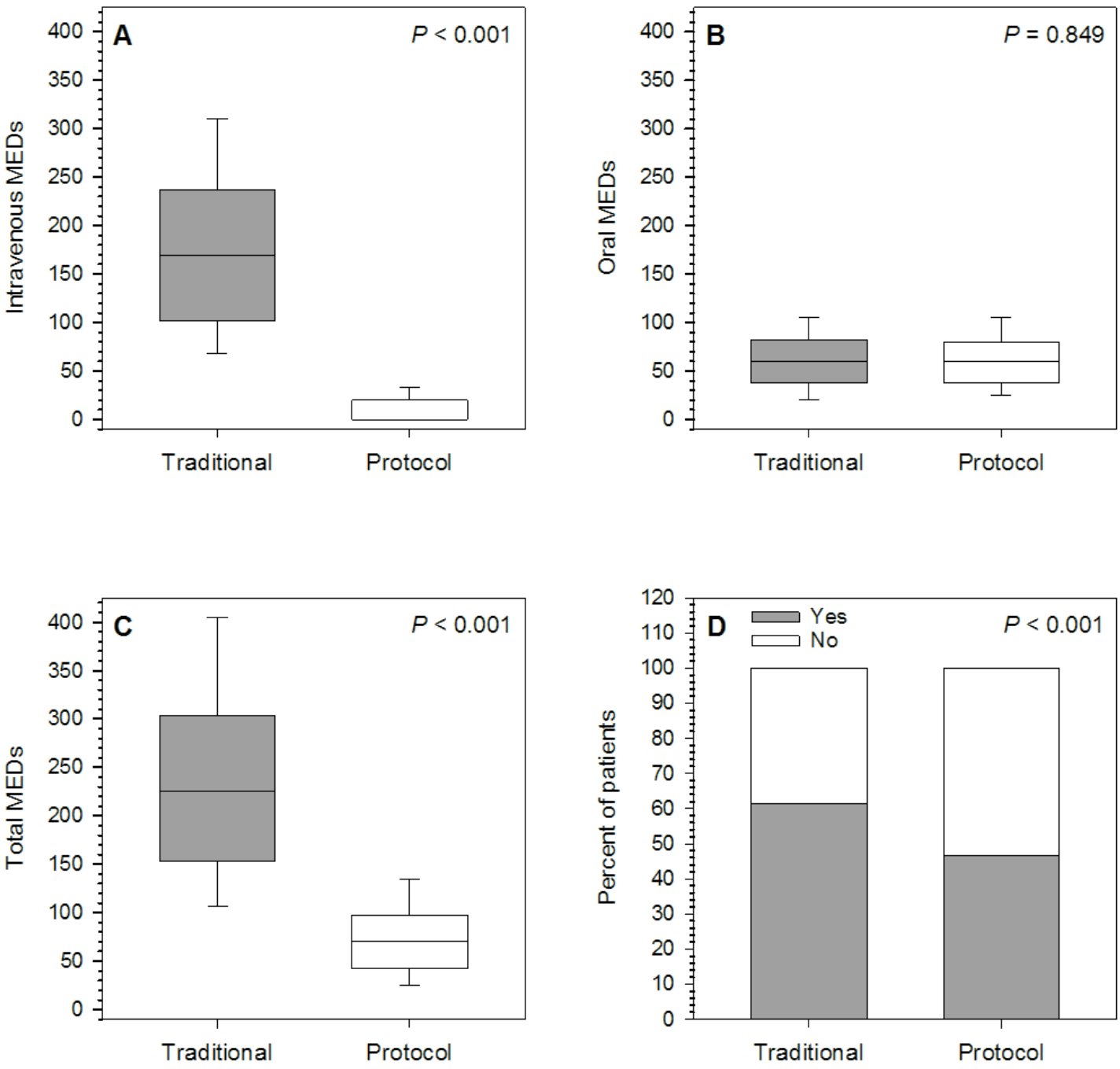

Figure 1

Opioid outcomes in the Traditional and Protocol groups. Intravenous opioid use was higher in the Traditional group (A). Oral opioid use did not differ between the two groups (B). Total opioid use (C) and refills (D) were higher in the Traditional group.

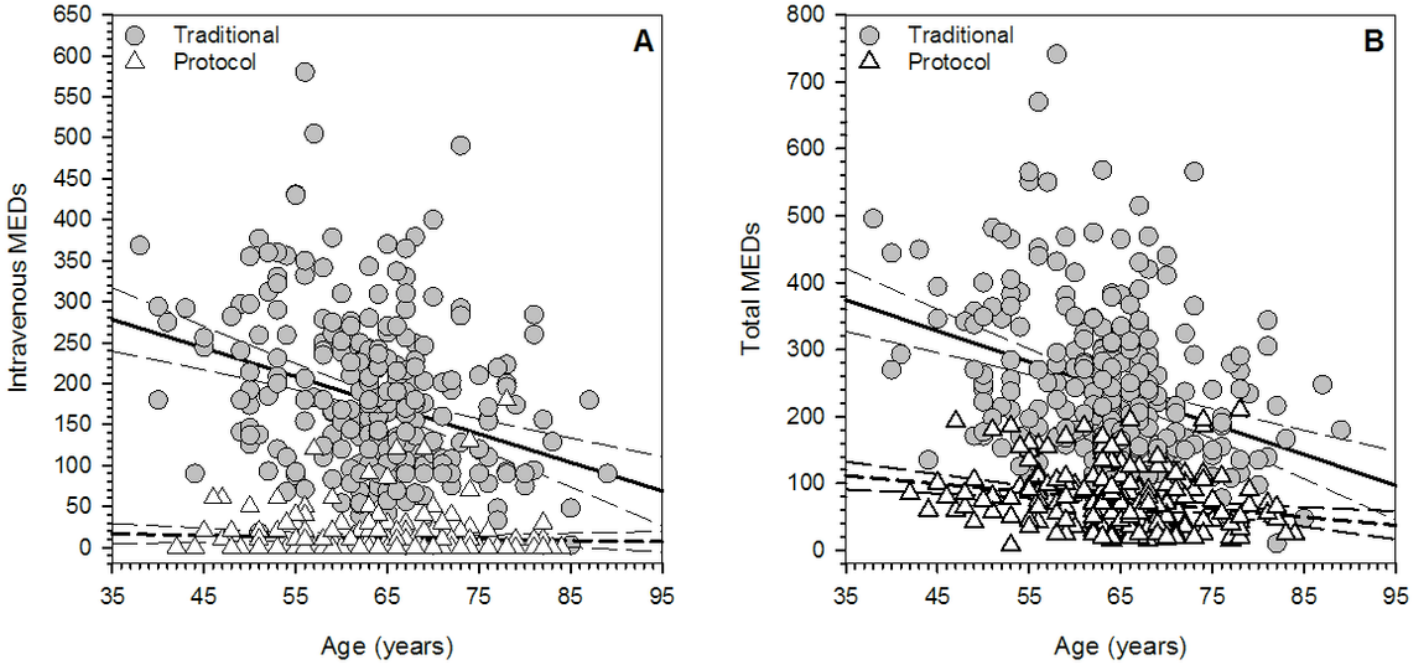

Figure 2

Interaction effect of age and group on opioid outcomes. Linear mixed models found significant ($p < 0.001$) age*group interaction effects for IV opioid use (A) and total opioid use (B). Solid regression lines = Traditional group (+/- 95% CI), dashed regression lines = Protocol group.

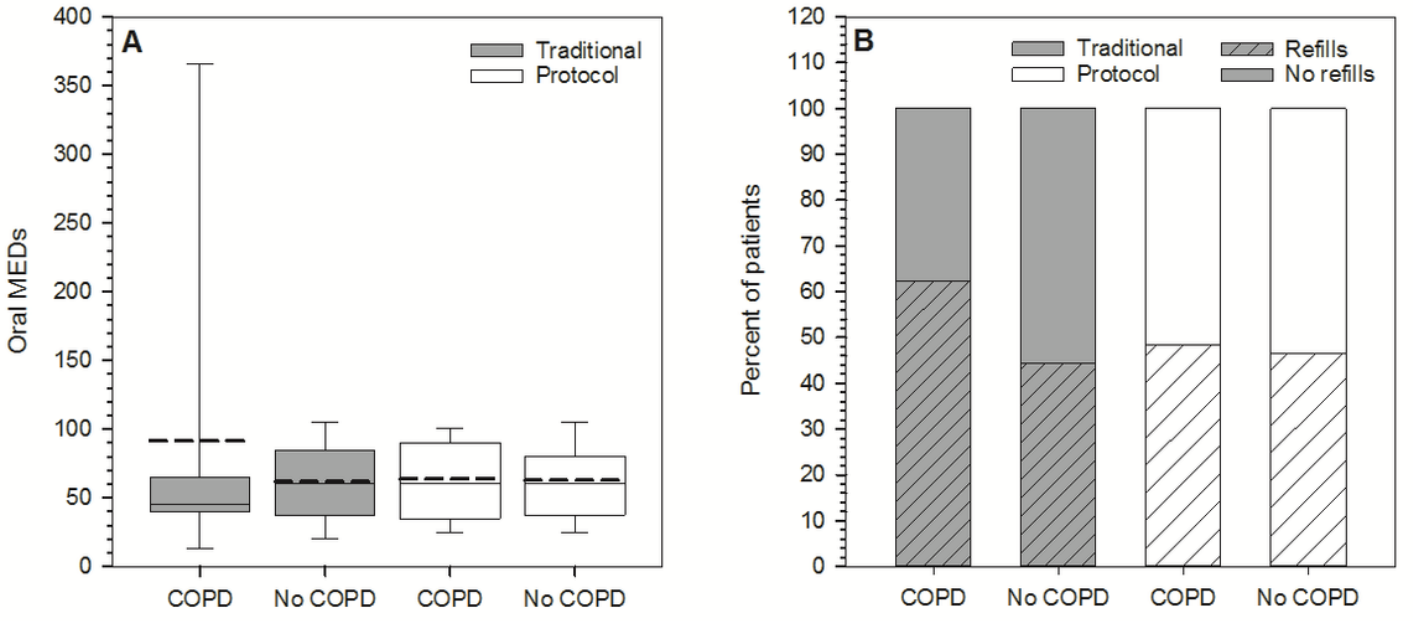

Figure 3

Interaction effect of COPD and group on opioid outcomes. (A) Traditional patients with COPD required higher mean oral opioids (91.5 ± 123.9 MED). Thick dashed lines represent their means. (B) Patients with COPD in the Traditional group required more opioid refills (p = 0.004).