Retrospective Review

Comorbid Insomnia and Sleep Apnea are Associated with Greater Downstream Health Care Utilization and Chronic Opioid Use after Arthroscopic Hip Surgery

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Background: There is a relationship between sleep, pain, and chronic opioid utilization. This has been poorly explored in general, and especially in patients undergoing orthopaedic surgery. Fewer studies have investigated this relationship based on a sleep diagnosis present both before and after surgery.

Objectives: To identify the association between insomnia and sleep apnea and downstream opioid use and medical utilization (visits and cost) in the 2 years following arthroscopic hip surgery.

Study Design: A retrospective cohort.

Setting: The US Military Health System.

Methods: This was a consecutive cohort of individuals undergoing hip arthroscopy in the Military Health System (MHS). Medical utilization data were abstracted from the MHS Data Repository between 2003 and 2015, representing 1 year prior and 2 years after surgery for every individual. Sleep disorder diagnoses (insomnia and sleep apnea) were identified using International Classification of Disease codes, and opioid utilization was determined from pharmacy data based on American Hospital Formulary Service codes 280808 and 280812. Sleep disorders present before surgery were used as predictors in multivariate logistic regression, and sleep disorders present after surgery were examined for associations with the outcomes using the Chi-square tests. The dependent variables in both cases were downstream medical utilization (costs, visits, and opioid use).

Results: Of 1870 eligible patients (mean age 32.3 years; 44.5% women), 165 (8.8%) had a diagnosis of insomnia before surgery and 333 (17.8%) after surgery; whereas 93 (5.0%) had a diagnosis of apnea before surgery and 268 (14.3%) after surgery. A diagnosis of insomnia before surgery predicted having at least 3+ opioids prescriptions after surgery (adjusted odds ratio, 1.97 [95% confidence interval, 1.39, 2.79]) and greater downstream total medical visits and costs in the 2 years after surgery. However, the number of individuals with a diagnosis of insomnia or apnea after surgery more than doubled, and was significantly associated with chronic opioid use, all-cause medical and all hip-related medical downstream visits and costs in the 2 years after surgery.

Limitations: The use of observational data and claims data are only as good as how it was entered.

Conclusions: Sleep disorders prior to surgery predicted chronic opioid use and medical utilization after surgery. However, a much higher rate of individuals had sleep apnea and insomnia present after surgery, which were significantly associated with chronic opioid use and greater total and hip-related medical utilization (visits and costs). Screening for sleep disorders prior to surgery may be important, but an even higher rate of sleep disorders may be developed after surgery, and continued screening after surgery may have greater clinical merit. Assessing quality of sleep during perioperative management may provide a unique opportunity to decrease pain and chronic opioid use after surgery.

Key words: Pain, opioid use, insomnia, sleep apnea, orthopaedic surgery, military medicine, health care utilization

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Quality sleep has been reported to have a strong association with physical health, mental health, and overall wellbeing (1). Insomnia, one of the most common sleep disorders, is thought to have a strong behavioral component, and is characterized by the inability to initiate or maintain sleep even when afforded the opportunity, having deleterious daytime effects on the patient (2). Insomnia appears to accompany many chronic diseases (3), in addition to chronic pain syndromes (4). This seems logical considering that sleep is a physiological necessity for maintaining balance of the body's own internal pain-regulation process (5). Patients with insomnia generally report greater levels of pain intensity (6), which may prompt them to use or be prescribed greater amounts of pain medication. Sleep disturbance is often reported after extensive surgeries (7). This may be especially true after hip surgery, which often comes with positional restrictions that affect sleep (e.g., activity restricted by physician; cannot sleep in certain positions, and others). Improved sleep before surgery has been shown to reduce pain intensity after surgery (8), and disrupted sleep after surgical procedures has been postulated as a catalyst for pain (9).

Opioid-based medication is often prescribed after orthopaedic surgery to manage postoperative pain. Beyond more common and expected side effects, such as nausea, constipation, impaired cognition, et cetera, other long-term or indirect side effects may also occur and often receive less attention by the medical team, perhaps because they are not as immediate and less understood. Clinicians and patients may not fully understand how opioids influence sleep, how sleep influences the perception of pain, and how the interaction may become more complicated after an extensive surgical procedure. This information has the potential to improve perioperative management for these patient, however, no studies were found that addressed downstream secondary health effects associated with opioid use or disturbed sleep after orthopaedic surgery (10). These downstream effects include the onset of comorbid conditions and the influence of opioid use on general health, both of which affect good quality sleep. Considering that military service members, who are relatively younger, have a higher proportion of sleep disorders (3,11), chronic pain (12,13), and propensity for chronic opioid use (14,15) compared with the general population, investigations of this nature are crucial and timely. Risk of disordered sleep is not currently a consideration for patients undergoing these procedures, and a better understanding of this relationship can result in more timely or preventative interventions.

The primary purpose of this study was to investigate the role of insomnia and sleep apnea present before surgery as predictors of downstream opioid use and medical utilization (visits and cost) in the 2 years following arthroscopic hip surgery. The secondary purpose was to assess the association between insomnia and sleep apnea diagnosed after surgery and the same outcomes (opioid use and medical utilization). As the presence of comorbid conditions often result in the need for additional medical care, the hypothesis was that individuals with a sleep disorder diagnosis before surgery would also have significantly greater opioid use and greater downstream medical utilization (visits and cots) after surgery. The secondary hypothesis was that the presence of sleep disorders, persistent or developing after surgery, would also be associated with greater chronic opioid use and greater downstream health care utilization.

Methods

Reporting Guidelines

This study used the REporting of studies Conducted using Observational Routinely collected Data (RECORD) initiative, which is an extension of the Strengthening of Reporting of Observational Studies in Epidemiology reporting guidelines. RECORD was created to improve the transparency of reporting of observational studies, such as cohort, case-control, and cross-sectional studies, and recommends minimum reporting standards for observational studies (16). Ethical approval for the study was granted by the Brooke Army Medical Center institutional review board.

Study Design

The study was a retrospective cohort of patients who underwent arthroscopic hip surgery between June 30, 2004 and July 1, 2013, with follow-up through July 2015.

Setting

Data were derived from the Military Health System Data Repository (MDR), which captures and tracks all medical visits for all beneficiaries of the Department of Defense (DoD) health care system—retired, active military, and service family members alike. Any medical visit, in a military or civilian setting worldwide, in which TRICARE insurance plan is the payer, is captured in MDR.

Patients

Any individual with a medical visit including an arthroscopic surgical hip procedure between June 30, 2004 and July 1, 2013, identified by Current Procedural Terminology (CPT) codes 29862, 29914, 29915, 29916, was included in the cohort. Surgical codes chosen for inclusion were confirmed for accuracy with the surgeons in the MHS that most often perform these surgeries. We attempted to identify individuals undergoing hip arthroscopy for femoroacetabular impingement (FAI) syndrome, however no International Classification of Diseases (ICD) code exists for FAI syndrome. All patients with potential confounding hip disorders present prior to the surgery, that might receive hip arthroscopy for a reason other than FAI syndrome, were excluded from the cohort (hip osteoarthritis, avascular necrosis of the femur, hip or pelvis fracture, infection, or neoplasm). FAI syndrome is a condition that affects primarily younger, more active individuals (mean age range of 27-35 years) (17,18), and the most common reason to undergo hip arthroscopy in young adults, including those in the military (19). Therefore, individuals < 18 or > 50 years of age were excluded. This provided a more homogenous sample that also happens to be consistent with the age range of most military service members (18). We chose hip surgery because it often requires periods of limited activity and mobility and requires adaptations to sleep position. We choose a younger military population because sleep disorders, chronic pain, and opioid misuse are all highly prevalent in this population (3,11,13,15). In addition, to ensure complete and accurate interpretation of medical utilization, individuals who were not continuously eligible for medical benefits from TRICARE during the entire 36-month period of surveillance (12 months prior and 24 months after surgery) were excluded. Details of the extraction for cohort have been published and are available (20).

Data Sources/Measurement

The MDR is the centralized data repository that captures, archives, validates, integrates, and distributes Defense Health Agency corporate health care data worldwide. It receives and validates data from a worldwide network of more than 260 health care facilities and from non-DoD data sources (21). MDR includes person-level data for all outpatient and inpatient medical visits, both in military hospitals and in the civilian network. It also includes all pharmacy data for any prescriptions filled. The data were pulled and aggregated by a senior health care analyst working for the Army Medical Command with over 10 years of experience, and who routinely retrieves and aggregates data of this nature. Data provided to the investigators were in both processed and raw form, in which every encounter with the health care system is listed line by line. All data variables in the processed file were validated with the raw data encounters independently by a different investigator (other than the health care analyst), and if any questions arose or further clarification was needed, then the issue was brought back to the senior analyst for consensus. Full details of the data extraction have been published (20).

Study Variables

Descriptive Variables

Patient characteristics captured included mean age, gender, branch of military service (i.e., Army, Coast Guard, Air Force, Marines, and Navy), rank category in military (categorized as enlisted or officer), and location of surgery (military or civilian hospital). Military rank serves as a proxy for socioeconomic status. Although some enlisted service members have education beyond high school (7.6%, 2015 data), officers commence service with a minimum of a 4-year bachelor's degree (22). Incomes are greater for higher ranking military officers, and although it is possible that their spouses have high incomes increasing the family's socioeconomic status, spouse income is unlikely to influence socioeconomic status more than rank. Fewer enlisted personnel (51%) are married compared with military officers (69.6%) (22). Finally, military-assigned housing is often geographically segregated by rank reflecting the military culture, for example, lower ranked enlisted personnel are typically housed in smaller homes in one geographic area, with senior officers in much larger homes in a different geographic area. This likely accentuates the "social" distinction more than in most other settings. Characteristics were reported according the presence of an insomnia or apnea diagnosis.

Independent Variables

Predictor Variables

Predictive modeling is the process of applying a statistical model or data mining algorithm to data for the purpose of predicting new or future observations (23). Predictive models can be appropriately used with observational data (23), and can include variables regardless of causality (24). Predictor variables must precede and be available at the time of prediction, and therefore, we utilized the presence of a medical diagnosis for insomnia and sleep apnea within 12 months prior to surgery.

Association Variables

We were also interested in the association between insomnia and apnea present after surgery and the same outcomes (opioid use and downstream medical utilization).

Patients were dichotomized as "yes" or "no" based on the presence of a medical visit with a sleep apnea or insomnia diagnosis (both before and after surgery). Insomnia was defined by a medical visit that included one of the following ICD codes: 307.41, 307.42, 327.00, 327.01, 780.52, and V69.4. Sleep apnea was defined by the ICD codes 320.20, 327.21, 327.22, 327.23, 327.24, 327.25, 327.26, 327.27, 327.29, 768.04, and 770.81. Codes were identified based on published guidelines for using sleep diagnosis codes in research (25), and further details of extraction for this cohort have been published (20). Studies show that apnea and insomnia are highly prevalent in military service members (11), and that these 2 sleep disorder co-occur often (11,26).

Outcome Variables (dependent)

Five outcomes variables were captured, which involved downstream health care utilization within a 2-year period following surgery: 1) opioid prescriptions, 2) all medical visits for any reason, 3) all medical costs for any reason, 4) hip-related medical visits, and 5) hip-related medical costs. Hip-related medical care included all visits for any diagnosis of the hip or pelvis and any procedures related to the hip, including imaging tests. Prescriptions opioids were identified from within MDR as medications with 280808 and 280812 American Hospital Formulary Service classification codes. As clinical practice often come down to dichotomous decisions (27), and skewed continuous data (e.g. health care costs and visits) are justified for dichotomization (28), we opted to dichotomize medical visits, costs, and days' supply of opioids. For chronic opioid use, we used 3 different definitions as used to describe chronic opioid use: 3+ prescriptions after the initial immediate perioperative prescription (29-31); still receiving new opioid prescriptions 1 year or later after surgery (32,33), and above the median total days' supply of opioids.

Comorbidities (confounding variables

Comorbidities were identified based on medical visits with relevant diagnosis codes. In recognition that a number of comorbidities can influence general health care utilization and specific use of physical therapy services, a number of comorbidities were captured: 1) metabolic disorders, 2) mental health, 3) chronic pain syndrome, 4) systemic arthropathy, 5) substance abuse, and 6) presence of a cardiovascular disorder. Specific details for how these variables were extracted, the exact diagnostic codes utilized, and their relevance in musculoskeletal outcomes has been published (20). These were identified as occurring any time in either the 12-month period before or 24-month period after surgery.

Statistical Analysis

All analyses were performed using SPSS version 23.0 (IBM Corporation, Armonk, NY). Study participant characteristics, including means, standard deviations (SD), and frequencies were reported and categorized by the presence of insomnia. Reporting of full sample characteristics was limited to postoperative data.

Because of the skewed nature of the health care utilization outcomes, which limits assumptions made with linear regression models, logistic regression analysis was performed for the predictor variables including all comorbidities as covariate controls. In addition, although dichotomizing outcomes in general can lead to bias, it is considered justified when the distribution of that variable is highly skewed, as was the case in this situation (28). Adjusted odds ratios (aOR) with 95% confidence intervals (CI), and P and Nagelkerke values were reported for each predictor variable. The Nagelkerke value is a pseudo R-squared measure that investigates the usefulness of the model (34). For assessing the association between sleep disorder variables occurring after surgery, 2 x 2 contingency tables with the Chi-square tests were run, reporting odds ratios with 95% CIs. Significance was set at 0.05.

Results

There were 1870 individuals that met the criteria during this timeframe. The mean age was 32.3 (SD, 8.08) years, the majority were men (55.5%), and from a lower socioeconomic status (76.3%). There was a greater proportion of patients with a diagnosis of insomnia from an enlisted household (83.6% vs. 75.6%) compared to an officer household, and the US Army was the only service with more individuals with insomnia (56.4%) than without (Table 1). If an individual had a diagnosis of insomnia prior to surgery, they were much more likely to also have a comorbid condition compared with those without an insomnia diagnosis (Table 2). The overall complication rate was minor for the entire cohort, and relatively no differences in complication rates after surgery based on the diagnosis of insomnia before surgery (Table 3).

From the entire cohort, 165 (8.8%) had a diagnosis of insomnia and 93 (5%) had a diagnosis of apnea at some point 12 months prior to surgery (Table 1). Of the 93 with sleep apnea, 29 also had insomnia prior to surgery, leaving 3.4% (n = 64) of the cohort with only apnea. This resulted in a small cell count that can lead to sparse data bias when running a logistic regression model, especially after adjusting for confounders (35). A sensitivity analysis was run regardless, and none of

Table 1. *Descriptive variables of the cohort-based diagnosis of insomnia or apnea prior to surgery.*

Variable n (%)	Total Sample 1870	Insomnia Absent 1705 (91.2)	Insomnia Present 165 (8.8)	*P* Value	Apnea Absent 1777 (95.0)	Apnea Present 93 (5.0)	*P* value
Mean age (SD)	32.2 (8.1)	32.2 (8.0)	32.58 (8.04)	0.56	31.9 (8.0)	38.2 (7.1)	<0.01*
Female gender	833 (44.5)	753 (43.1)	80 (48.5)	0.29	809 (45.5)	24 (25.8)	<0.01*
Beneficiary category				0.19			0.70
Active duty	1263 (67.5)	1160 (68.0)	103 (62.4)		1196 (67.3)	67 (72.0)	
Dependent	420 (22.5)	376 (22.1)	44 (26.7)		402 (22.6)	18 (19.4)	
Guard/Reserve	6 (0.3)	6 (0.4)	0		6 (0.3)	0	
Retired Service Member	22 (1.2)	22 (1.3)	0		22 (1.2)	0	
other/unknown	159 (8.5)	141 (8.3)	18 (10.9)		151 (8.5)	8 (8.6)	
Service							0.17
Army	833 (44.5)	740 (43.4)	93 (56.4)		794 (44.7)	39 (41.9)	
Air Force	467 (25.0)	429 (25.2)	38 (23.0)	0.01*	29 (1.6)	1 (1.1)	
Navy	305 (16.3)	291 (17.1)	14 (8.5)		434 (24.5)	33 (35.5)	
Marines	225 (12.0)	208 (12.2)	17 (10.3)		219 (12.3)	6 (6.5)	
Coast Guard	30 (1.6)	28 (1.6)	2 (1.2)		291 (16.4)	14 (15.1)	
other	8 (0.4)	8 (0.5)	0		8 (0.5)	0	
missing	2 (0.1)	1 (0.1)	1 (0.6)		1 (0)	1 (1.1)	
Socioeconomic status: enlisted rank[a]	1427 (76.3)	1289 (75.6)	138 (83.6)	0.01*	1348 (76.1)	79 (84.1)	0.05*
Location of surgery: military hospital[b]	967 (51.7)	875 (51.3)	92 (55.8)	0.28	926 (52.1)	41 (44.1)	1.31
Hip-related medical visits: mean (SD)	27.95 (26.37)	27.63 (26.29)	30.76 (27.09)	0.15	28.0 (26.6)	26.5 (20.3)	0.60
Hip-related medical costs: mean (SD)	$15,447.74 (17,024.73)	$15,364.32 (17,152.21)	$16,155.19 (15,549.57)	0.57	$15,502.27 ($17,104.09)	$14,131.64 ($15,225.45)	0.45
Individuals using opioids prior to surgery	918 (49.1)	826 (48.4)	92 (55.8)	0.17	723 (40.7)	38 (40.9)	0.97
Individuals with 3+ opioid prescriptions after surgery	727 (38.9)	630 (37.0)	97 (58.8)	< 0.01*	727 (43.2)	40 (45.5)	0.68
Mean total days' supply of opioids after surgery (SD)	44.0 (137.1)	45.0 (140.6)	34.4 (93.8)	0.34	43.5 (137.3)	54.4 (134.4)	0.45
Insomnia diagnosis before surgery	165 (8.8)				136 (7.7)	29 (31.2)	<0.01*
Apnea diagnosis before surgery	93 (5.0)	64 (3.8)	29 (17.6)	< 0.01*			
Insomnia diagnosis after surgery	333 (17.8)	248 (14.5)	85 (51.5)	< 0.01*	307 (17.3)	26 (28.0)	< 0.01*
Apnea diagnosis after surgery	268 (14.3)	225 (13.2)	43 (26.1)	< 0.01*	201 (11.3%)	67 (72.0)	< 0.01*

n (%) unless otherwise noted. *Significant at $P < 0.05$. [a]Compared to officer rank; [b]compared civilian hospital. All comparative analyses include the t tests and the Chi-square test (the Fisher exact test when appropriate).

Table 2. *Presence of comorbid conditions present before surgery based on diagnosis of insomnia before surgery.*

Variable	Total Sample (n = 1870)	Individuals without Diagnosis of Insomnia (n = 1705)	Individuals with Diagnosis of Insomnia (n = 165)	*P* value
Post-traumatic stress disorder	67 (3.6)	40 (2.3)	27 (16.4)	< 0.01*
Metabolic disorder	297 (15.9)	255 (15.0)	42 (25.5)	< 0.01*
Systemic arthropathy	34 (1.8)	30 (1.8)	4 (2.4)	0.54
Mental health disorder	372 (19.9)	286 (16.8)	86 (52.1)	< 0.01*
Cardiovascular disorder	198 (10.6)	173 (10.1)	25 (15.2)	0.04*
Substance abuse disorder	288 (15.4)	253 (14.8)	35 (21.2)	0.03*
Chronic pain diagnosis	174 (9.3)	148 (8.7)	26 (15.8)	< 0.01*

Values present number of unique individuals (% of total in column). *Significant at $P < 0.05$

Table 3. *Complication rate within 2 years of surgery based on insomnia diagnosis.*

Variable	Total Sample (n = 1870)	Individuals without Diagnosis of Insomnia (n = 1705)	Individuals with Diagnosis of Insomnia (n = 165)	*P* value
Hip fracture	31 (1.7)	26 (1.5)	5 (3.0)	0.15
Avascular necrosis	8 (0.4)	6 (0.4)	2 (1.2)	0.11
Hip stress fracture	3 (0.2)	3 (0.2)	0	0.59
Hip infection	5 (0.3)	2 (0.1)	3 (1.8)	<0.01*
Hip arthroplasty	29 (1.6)	24 (1.4)	5 (3)	0.11
Heterotrophic ossification	12 (0.6)	11 (0.6)	1 (0.6)	0.95

Values present number of unique individuals (% of total in column). *Significant at $P < 0.05$

Table 4. *Predictive value of sleep disorders on health-related outcomes of visits, costs, and opioid prescriptions after surgery.*

Outcome Variable	aOR (95% CI)	*P* value	Model Nagelkerke
Presence of Insomnia Diagnosis Before Surgery			
Still taking opioids at 1 year after surgery	1.15 (0.81, 1.66)	0.42	0.02
Total days' supply of opioids†	1.27 (0.80, 2.03)	0.31	0.31
Three or more opioid prescriptions within 2 years	1.97 (1.39, 2.79)	< 0.01	0.07
Total health care visits†	1.53 (1.06, 2.21)	0.02	0.10
Total health care costs†	1.44 (1.02, 2.05)	0.04	0.04
Total hip-related health care visits†	1.38 (0.98, 1.94)	0.06	0.02
Total hip-related health care costs†	1.16 (0.83, 1.62)	0.39	0.02

†Outcomes dichotomized by median value. Control variables include postoperative hip infection, service branch, socioeconomic status, and presence of preoperative post-traumatic stress disorder, metabolic disorder, mental health disorder, cardiac disorder, substance abuse, and chronic pain

the downstream health care utilization and opioid use variables were significantly predicted by a presurgery diagnosis of apnea. Therefore, the descriptive statistics are provided for apnea in Table 1, but we provided the predictive model only for insomnia (Table 4).

A diagnosis of insomnia prior to surgery significantly predicted greater chronic opioid utilization (aOR, 1.97; 95% CI, 1.39, 2.79), greater likelihood of having above median total health care costs (aOR, 1.44; 95% CI, 1.02, 2.05), and greater likelihood of having above median total health care visits (aOR, 1.53; 95% CI, 1.06, 2.21) in the 2 years following surgery (Table 4).

Insomnia was not a significant predictor of hip-related visits and costs.

Regarding associations between insomnia and apnea diagnosis rendered after surgery, the relationship was stronger. After surgery, the number of individuals with insomnia more than doubled (N = 333; 17.8%), and with apnea almost tripled (N = 268; 14.3%). Over half of the individuals with an insomnia diagnosis before surgery also had one after surgery (51.5%), whereas 14.5% of those without a diagnosis before had the diagnosis after surgery (Table 1). A diagnosis of insomnia or apnea after surgery was significantly associated with greater downstream total and specifically hip-related health care utilization compared with those without the diagnosis (Table 5). Presence of either diagnosis after surgery was also significantly associated with a greater likelihood of having 3+ unique opioid prescriptions beyond the initial perioperative period, and in those with a postsurgery insomnia diagnosis, a greater likelihood of still receiving opioid prescriptions 1 year after surgery (Table 5).

Discussion

In this cohort of patients undergoing arthroscopic hip surgery, a comorbid diagnosis of insomnia before surgery was a predictor for greater downstream opioid and medical care utilization in the 2 years following surgery. The proportion of individuals with sleep disorder more than doubled after surgery. A diagnosis of apnea and insomnia rendered after the surgery was associated with greater chronic opioid utilization and greater downstream health care utilization (costs and visits). These results suggest that screening for sleep disorders prior to surgery may not be enough and may need to continue after surgery, in which the diagnosis may become more prevalent. Early screening and intervention approaches before and after surgery (e.g., patient education, referrals to sleep specialists, and others) may have merit.

Although these data are observational, can have varied interpretations, and no causal implications can be made, the associations are of interest because they support the notion that there is a relevant relationship between sleep, pain, and opioid utilization. Further, the data from this study represent a longitudinal trend in outcomes, demonstrating the potential long-term side effects of rendered care pathways. They also suggest that screening for sleep disorders prior to surgery may not be enough, as the majority of disorders may develop after surgery. Pain control is a primary goal of medical care following surgery, and a better understanding of these relationships can potentially help improve how that goal is achieved. These relationships are also extremely relevant considering the disproportionately higher rates of opioid use, chronic pain, and sleep disorders found in military veterans compared with the general population (11,13,14). These findings serve to generate hypotheses for future prospective trials that look at improving quality of sleep by improving the effectiveness of pain management strategies or decreasing pain by focusing on effective sleep strategies. They also provide rationale for more holistic approaches to managing patients, which are multifactorial and consider how overlapping health determinants may affect outcomes. For example, sleep specialists could potentially become a more integrated part of the perioperative medical plan in patients undergoing orthopaedic surgery.

There is a strong relationship between sleep and pain, so it is not surprising that a subset of patients with musculoskeletal pain also

Table 5. ***Association between sleep disorders and health-related outcomes after surgery (medical visits, costs, and opioid prescription).***

Outcome Variable	OR (95% CI)	*P* value
Presence of Insomnia Diagnosis After Surgery		
Still taking opioids at 1 year after surgery	2.50 (1.90, 3.28)	< 0.01*
Total days' supply of opioids†	1.21 (0.95, 1.53)	0.126
Three or more opioid prescriptions within 2 years	2.54 (1.97, 3.26)	< 0.01*
Total health care visits†	3.48 (2.67, 4.53)	< 0.01*
Total health care costs†	2.59 (2.01, 3.34)	< 0.01*
Total hip-related health care visits†	1.72 (1.35, 2.19)	< 0.01*
Total hip-related health care costs†	1.27 (1.00, 1.62)	0.046*
Presence of Apnea Diagnosis After Surgery		
Still taking opioids at 1 year after surgery	1.34 (1.01, 1.78)	0.039
Total days' supply of opioids†	0.91 (0.70, 1.19)	0.494
Three or more opioid prescriptions within 2 years	1.64 (1.27, 2.13)	< 0.01*
Total health care visits†	2.21 (1.69, 2.91)	< 0.01*
Total health care costs†	2.25 (1.71, 2.96)	< 0.01*
Total hip-related health care visits†	1.68 (1.28, 2.19)	< 0.01*
Total hip-related health care costs†	1.35 (1.04, 1.75)	< 0.025*

†Outcomes dichotomized by median value. *Significant at $P < 0.05$.
Abbreviations: OR, odds ratio.

had comorbid insomnia or sleep apnea present before and after surgery. Even if the surgery is successful in the long run, there is an immediate period of postoperative pain during recovery from surgery, and therefore, pain is a relevant issue both before and after surgery. Arthroscopy is a common procedure used to treat hip pain thought to be related to FAI syndrome, and therefore, pain was likely the common precursor driving the decision to have surgery. Indeed, insomnia is an independent risk factor for developing chronic pain (6), and it can occur independent of pain intensity (6). Poor sleep can adversely influence pain perception (5), increases anxiety, and affects the body's ability to regulate cortisol in response to stress (36). The relationship between sleep and pain is bidirectional (37), in that greater pain intensity leads to worse sleep, and worse sleep leads to higher pain intensity. One single night of total deprived sleep can promote generalized hyperalgesia (38). Patients with no history of sleep disorders may become predisposed to them after the surgical experience.

Although the rates of sleep disorder diagnoses rose substantially after surgery, many who had the diagnosis afterward were not the same patients who had it before. Those without the diagnosis afterward could represent a small subset of individuals in which poor sleep was exacerbated by pain prior to surgery, but when surgery ameliorated symptoms their sleep was improved. Given that many more had the diagnosis after surgery, this could also reflect a subset with perioperative pain secondary to the invasive surgical procedure, which then adversely affected sleep following the procedure. The patients with insomnia or sleep apnea after surgery were also much more likely to be chronic opioid users.

Opioid medication, taken presumably for persistent pain, can also adversely affect the quality of sleep. Opioids are a major contributor to hypoxemia and apnea-related sleep disorders (39). Indeed, established sleep patterns can be disrupted after one single dose of opioids in healthy adults (40). With acute use of opioids, rapid eye movement and overall sleep time, as well as overall efficiency of sleep, decrease significantly (41). Some drugs meant to treat pain and improve sleep can actually do the opposite and disrupt sleep and increase pain (42). Therefore, it is not difficult to imagine an interdependent cycle in which pain from a surgical procedure leads to poor sleep, poor sleep leads to heightened pain perception, which leads to an increased use of opioids, and then opioids negatively affect the body's ability to achieve quality sleep. Although the exact mechanisms of this relationship require further investigation, these adverse health effects may very well be related (directly or indirectly) to the surgical procedure.

There has been less research investigating the relationship between pain and breathing-related sleep disorders, such as apnea. However, there are reports that the interaction may be similar to that of insomnia (43). Sleep apnea is also a risk factor for complications after joint replacement surgery (44), and chronic opioid use is associated with (45), and a risk factor for, developing sleep apnea (46). It is surprising that sleep apnea rates were lower than insomnia rates in this cohort, as apnea was shown to be the most common sleep disorder found in a similar demographic of patients (11), although they are relatively younger compared to the typical civilian counterpart with an apnea diagnosis. The relatively fewer cases of sleep apnea in our cohort before surgery made it difficult to identify any meaningful predictive value for the diagnosis preoperatively.

Sleep disturbance may significantly alter pain processing in some individuals, regardless of the specific sleep etiology or diagnosis. Assessing quality of sleep during the initial patient assessment prior to surgery, as well as continued assessment following surgery, may reveal an important opportunity for interventions. Specifically, this could include screening for disordered sleep as part of the intake prior to surgery, as well an opportunity to integrate sleep specialists as part of the medical care team to assist with coordinating the plan of care both before and after surgery. Improving the quality of sleep during this time may help improve outcomes and quality of life in this population. The surgical consent process may provide an opportunity to educate patients about the potential relationship between pain, sleep, and chronic opioid use. This relationship between pain and different sleep disorders would benefit from further investigation in prospective trials, as the treatments for each of these different sleep pathologies vary.

Limitations

As with most observational data, cause and effect cannot be implied. The results from analyses of observational data rely heavily on the interpretation of the researchers and can be influenced by confounders that are beyond statistical control. Based on the inherent limitations associated with coding in electronic medical records, greater detail is lacking about the severity, extent of the sleep disorders, and even validity of the diagnoses. It is possible that increased exposure to medical providers during perioperative assessments following surgery led to higher rates of documentation of apnea and insomnia. In addition, self-reported variables from patients, such as pain intensity, specific nature of the sleep disturbance, and self-reported function and quality of life would add greater clarity to the exact nature of these relationships, but do not exist in claims data. It is also quite possible that other variables not captured from this cohort can provide improved clarity on downstream opioid use. These include variations in surgical procedures, or different types of pain control approaches during the actual surgery (e.g., regional block vs. general). There has been increased focus recently on optimizing these approaches to minimize postoperative opioid use (47). Finally, details of the exact onset and timing of symptoms before and after surgery are lacking and are needed to better understand the relationship between pain, opioid use, and sleep quality before and after surgery.

Conclusions

Comorbid insomnia prior to hip surgery predicted greater opioid utilization and higher medical visits and costs in the 2 years following surgery compared with nondiagnosed individuals. However, insomnia and apnea rates more than doubled after surgery, and were significantly associated with chronic opioid use, greater downstream total and hip-related medical visits and costs in the 2 years after surgery. These results suggest that identifying the presence of insomnia prior to hip surgery may have value, but perhaps more impactful is the screening for sleep disorders that may occur after surgery. Assessing and addressing quality of sleep as part of the perioperative management for patients, both before and after hip surgery, may be one approach to helping decrease pain and chronic opioid use after surgery.

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