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Bone Health Management in Elective Orthopaedic Surgery: A Claims-Based Observational Study

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Abstract

Introduction: There are limited data on the management of bone health, including bone mineral density (BMD) evaluation and osteoporosis (OP) treatment, in patients undergoing elective orthopaedic surgeries. **Methods:** This was a retrospective cohort study using administrative claims data from Symphony Health, PatientSource for patients aged ≥50 years with documented kyphoplasty/vertebroplasty (KP/VP), total knee arthroplasty (TKA), and total hip arthroplasty (THA). Risk stratification to identify patients at very high risk for fracture (VHRFx) was based on clinical practice guideline recommendations to the extent information on variables of interest were available from the claims database. **Results:** A total of 251 919 patients met inclusion criteria: KP/VP (31 018), TKA (149 849), and THA (71 052). The majority were female (80.3%) with a mean (SD) age of 68.5 (7.5) years. Patients undergoing KP/VP were older and had a greater comorbidity burden associated with risk for falls, mobility issues, muscle weakness, and respiratory and cardiovascular diseases. In the 6 months before surgery, 11.8% of patients were tested and/or received treatment for OP. Patients undergoing KP/VP were more likely to be tested and/or treated (17.5%) than patients undergoing TKA (11.0%) or THA (10.9%). Overall, men had a lower rate of testing and/or treatment than women (4.6% vs 13.5%). In the 12 months before surgery, patients with an OP diagnosis and at VHRFx (30.8%) had a higher rate of treatment and/or testing than those without OP (11.5%), or those without OP but with a fracture in the year preceding surgery (10.2%). **Conclusions:** Bone health management is suboptimal in patients undergoing elective orthopaedic surgeries and is worse in men than in women. Proper management of OP before and after surgery may improve outcomes.

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Correction (December 2023): This article has been updated to add authors' initials in the Declaration of Conflicting Interests section.

Data Availability Statement included at the end of the article

Keywords
osteoporosis, vertebroplasty, kyphoplasty, total knee arthroplasty, total hip arthroplasty, orthopaedic surgery, bone health

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Introduction

The American Academy of Orthopaedic Surgeons considers osteoporosis (OP) a national public health priority and encourages ongoing education of physicians to improve health care delivery of bone health, including better management of OP to reduce secondary fracture rates.[1,2] Recently issued OP clinical practice guidelines provide a pathway for identifying patients at high risk for fragility fractures.[3] Currently, however, there are no specific guidelines for OP assessment or its management in patients undergoing elective orthopaedic surgery despite the recognized importance of bone quality and strength on surgical outcomes.

Periprosthetic fractures (PPfx) are a common osteoporosis-related complication following surgery. These fractures may occur due to a decrease in bone mineral density (BMD), compromised bone quality and changes in bone microarchitecture associated with OP itself, or with the accelerated postoperative bone loss due to immobilization following surgery.[4] The incidence of postoperative PPfx varies and is as high as 18% for some procedures. These fractures are associated with increased hospital readmission.[5-7]

The use of antiresorptive therapies has been associated with inhibition of bone loss and increases in BMD following total knee (TKA) and total hip arthroplasty (THA).[8,9] While bisphosphonates do not clearly improve bone formation or fusion after spinal surgery,[10] adjuvant use of anabolic therapy for surgical treatment of femoral fractures has been shown to improve the bone healing process.[11] Improved bone strength and healing through the use of anabolic therapies following surgical fracture repair may reduce the burden and cost of illness for OP patients. A study by Labuda et al[12] (n = 362) determined that 26% of patients with osteoarthritis undergoing TKA or THA also had OP, yet only 37% and 17% were being treated for OP, respectively. Further, these low percentages are likely underestimates since the diagnosis of OP was self-reported by patients in this study. According to a study using the National Inpatient Database, approximately 7.2 million US adults had a knee or hip replacement surgery in 2010.[13] As the US population ages, we can expect to have a larger number of older patients with OP and with a greater associated disease burden undergoing orthopaedic surgery. Assessment of current practices and characterization of patients undergoing elective orthopaedic surgeries will help to identify opportunities to improve OP management and outcomes of surgeries in this patient population.

The primary objective of the study was to assess the number of orthopaedic surgeries overall and by type of surgery (kyphoplasty/vertebroplasty [KP/VP], TKA, THA) for: 1) patients with OP, 2) patients with OP and at very high risk for fracture (VHRFx), 3) patients without a diagnosis of OP but with an OP-related fracture in the year preceding surgery, and 4) patients without a diagnosis of OP. The second objective of the study was to evaluate management of patients undergoing orthopaedic surgeries, including dual energy x-ray absorptiometry (DXA) or other imaging studies (ie, computed tomography [CT] scan, ultrasound) to assess BMD and OP treatment as defined as having ≥1 pharmacy claim for OP medication dispensed in the 6 months before and 12 months after the surgery.

Methods

This was a retrospective cohort study using administrative claims data aggregated across multiple payers. Data for the study were maintained in a deidentified manner; as such, the data is exempt from review by institutional review boards and were accessed following protocols compliant with the Health Insurance Portability and Accountability Act (HIPAA) and in compliance with 45 CFR 164.514(a)-(c) a. Pharmacy and medical claims data from Symphony Health, an ICON plc Company, PatientSource, containing patient-level data for more than 280 million US-based commercial and Medicare enrollees, were used for this study. Through its licensing agreement, Radius receives data on patients who have an OP diagnosis, a fracture, or have any OP medication dispensed.

The index date was the date of the first medical claim for an orthopaedic surgery anytime between May 1st, 2017 and May 31st, 2020 (identification period) (Figure 1). Preindex duration varied for all patients and included data prior to the index date as far back as available (September 2011). The postindex period included data after the index orthopaedic surgery date through May 31st, 2021. If a patient had multiple orthopaedic surgeries during the identification period, only the first surgery was selected for evaluation of bone health management.

All patients were required to have medical history data 12 months preindex as indicated by the presence of a

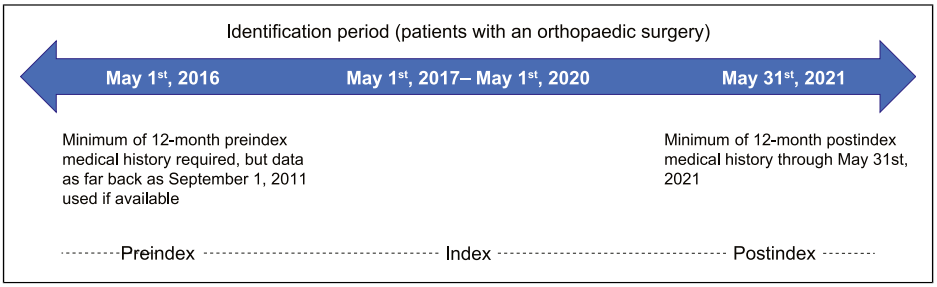

Figure 1. Study Timeline.

medical or hospital claim in the period of 9 to 14 months before the index date, and data as far back as September 1, 2011, were used if available (Figure 1). For evaluation of OP treatment, patients were also required to have a minimum of 12 months of postindex data availability (indicated by a claim within 9-14 months); however, all available data beyond 12 months were utilized for assessment of fracture events and OP treatment.

Population

Patients aged ≥50 years on the index date were included in this study. For the initial analysis of patients undergoing orthopaedic surgeries, no exclusion criteria were applied. For evaluation of management of patients undergoing surgeries, patients with Paget disease of the bone or malignancies (except for nonmelanoma skin cancer, carcinoma in situ of cervix, or ductal carcinoma in situ of breast) were excluded.

Variable Definitions

Current Procedural Terminology (CPT) codes were used to identify patients undergoing orthopaedic surgery and to exclude patients with revision surgeries (Appendix A). CPT codes were also used to identify procedures completed for the assessment of bone health including x-ray or DXA scan (Appendix B). National Drug Codes (NDC) were used to identify patients with ≥1 OP medication prescription filled and dispensed (Appendix C). Patients with OP were identified by the presence of ≥1 medical inpatient or outpatient claim for OP using ICD-10-CM codes and ICD-9-CM codes for claims generated prior to October 15, 2015 (Appendix D). Variables of interest for fracture risk assessment were defined from the AACE 2020 clinical practice guidelines (Appendix E), and we used medical and pharmacy claims for conditions and/or drugs associated with higher risk for fracture to the extent information on these variables of interest was available from the claims database to determine VHRFx. Patients at very high fracture risk, according to the American Association of Clinical Endocrinology (AACE), include those with a recent fracture (eg, within the past 12 months), fractures while on approved osteoporosis therapy, multiple fractures, fractures while on drugs causing skeletal harm (eg, long-term glucocorticoids), a very low T-score (eg, less than −3.0), high risk of falls or history of injurious falls, and a very high fracture probability by FRAX (eg, 10-year probability of major osteoporosis fracture >30%, 10-year probability of hip fracture >4.5%) or other validated fracture risk algorithm (Table 1). In the current study, information regarding patient T-scores or lifestyle risk factors used to determine FRAX score were not available, the remaining AACE factors were used to determine which patients were at VHRFx.

Statistical Analyses

Logistic regression models were created to evaluate predictors of postsurgical OP treatment for each type of surgery and by sex. The Hosmer and Lemeshow test was used for goodness of fit of the model. The dependent variable was treatment with any OP medication (antiresorptive or anabolic) in the 12-month period following the orthopaedic surgery. Subgroup analyses were carried out for patients ≥65 years of age including an assessment of OP management in the 24-month period prior to each surgery.

Results

Study Population

A total of 251 919 patients met the study inclusion criteria (Table 2). Of these, 31 018 had KP/VP, 71 052 with THA, and 149 849 with TKA. The majority of patients undergoing all surgeries were female (80.3%) and 60.9% were ≥65 years of age. The mean (SD) age was 68.5 (7.5) years. Patients with KP/VP were, on average, older (72.1 [7.0]) than those with THA (67.9 [7.6]) or TKA (68.1 [7.3]). The most common comorbidities included cardiovascular disease (89.5%), hypertension (78.1%), arthritis (94.7%), and respiratory disease (56.9%). Patients undergoing KP/VP had a greater history of falls, mobility

Table 1. AACE definition of Very High Risk of Fracture.

Patients are Considered at Very High risk of Fracture according to American Association of Clinical Endocrinology (AACE) 2020 Clinical Practice Guidelines if They Have
✓ A recent fracture (eg, within the past 12 months)
✓ fractures while on approved osteoporosis therapy
✓ multiple fractures
✓ fractures while on drugs causing skeletal harm (eg, long-term glucocorticoids)
✓ A very low T-score (eg, less than −3.0)[a]
✓ A high risk of falls or history of injurious falls
✓ A very high fracture probability by FRAX (eg, 10-year probability of major osteoporosis fracture >30%, 10-year probability of hip fracture >4.5%) or other validated fracture risk algorithm[a]

[a]Information regarding patient T-score and lifestyle fractures used to determine FRAX score.

Table 2. Attrition Table (all Surgeries).

	n	%
Patients with an orthopaedic surgery (index) between May 1st, 2017 and May 31st, 2020	507 706	100.00
Complete and concordant demographic information	506 128	99.69
Patients with 12-month preindex data availability	388 522	76.52
Patients with 12-month postindex data availability	317 668	62.57
Age ≥50 years	310 345	61.13
No evidence of Paget disease of the bone preindex through 30 days postindex	309 916	61.04
No evidence of cancer preindex through 30 days postindex[c]	251 919	49.62

[a]Presence of a medical or hospital claim in the 9- to 14-month period before the index date.
[b]Presence of a medical or hospital claim within the 9- to 14-month period after the index date.
[c]Except for nonmelanoma skin cancer, carcinoma in situ of cervix, or ductal carcinoma in situ of breast.

issues, muscle weakness, and respiratory and cardiovascular disease.

Osteoporosis Disease Status

Approximately one-third (85 539/251 919 [34.0%]) of all patients had a medical diagnostic claim for OP, and 25.1% (63 127/251 919) were also at VHRFx. A higher proportion of patients undergoing KP/VP (14 664/31 018 [47.3%]) had a history of OP as determined by the presence of a diagnostic claim for OP compared to those undergoing THA (22 996/71 052 [32.4%]) or TKA (47 879/149 849 [32.0%]) (Table 3). Compared to men, a greater proportion of women had a history of OP (overall, 38.8% of women vs 14.2% of men; for KP/VP, 55.0% vs 22.5%; THA, 37.8% vs 12.8%; and TKA, 36.2% vs 12.7%).

Approximately 46.8% of those with KP, 22.9% of those with THA, and 21.6% of those with TKA had an OP diagnostic code and were also considered to be at VHRFx. When evaluated separately, a larger proportion of both women and men at VHRFx were undergoing KP compared with THA or TKA (women: KP, 54.5%; THA, 26.7%; and TKA, 24.3%; men: KP, 22.3%; THA, 9.2%; and TKA, 8.9%).

Compared to women, a higher proportion of men undergoing orthopaedic surgery had a fracture in the year preceding their surgery but did not have an OP diagnostic history (17.1% vs 7.7%). Among those undergoing KP/VP, 71.0% of men vs 41.5% of women had a fracture. The trend was also consistent for THA, for which 13.2% of men compared with 5.8% of women had a fracture and, for TKA, for which 4.6% of men compared to 2.0% of women had a fracture.

Osteoporosis Management

In the 6-month period prior to surgery, about 12% of patients (29 626/251 919) had DXA and/or treatment with OP medications. A higher proportion of patients undergoing KP/VP had an imaging test or had an OP medication dispensed (5434/31 018 [17.5%]) compared to those undergoing THA (7720/71 052 [10.9%]) or TKA (16 472/149 849 [11.0%]) (Figure 2). Compared to women (27 355/202 236 [13.5%]), men had a lower rate of testing and/or treatment (2271/49 683 [4.6%]) (Figure 3). Fewer than ten percent (14 411/202 236 [7.1%]) of women were tested in the 6 months prior to their surgery, and

Table 3. Baseline Patient Characteristics and Osteoporosis Disease Status before Surgery by Orthopaedic Procedure.

	Any Surgery	Kyphoplasty/ vertebroplasty	Total hip Arthroplasty	Total Knee Arthroplasty
All patients, N	251 919	31 018	71 052	149 849
Sex, n (%)				
Female	202 236 (80.3)	23 675 (76.3)	55 579 (78.2)	122 982 (82.1)
Male	49 683 (19.7)	7343 (23.7)	15 473 (21.8)	26 867 (17.9)
Age, mean (SD)	68.5 (7.5)	72.1 (7.0)	67.9 (7.6)	68.1 (7.3)
OP, n (%)	85 539 (34.0)	14 664 (47.3)	22 996 (32.4)	47 879 (32.0)
OP and VHRFx, n (%)	63 127 (25.1)	14 529 (46.8)	16 290 (22.9)	32 308 (21.6)
No OP, but Fx in preceding year, n (%)	23 967 (9.5)	15 028 (48.5)	5235 (7.4)	3704 (2.5)
No OP, n (%)	166 380 (66.1)	16 354 (52.7)	48 056 (67.6)	101 970 (68.1)
Comorbid arthritis, n (%)	238 465 (94.7)	19 564 (63.1)	69 162 (97.3)	149 739 (99.9)

Fx = fracture, OP = osteoporosis, SD = standard deviation, VHRFx = very high risk for fracture.

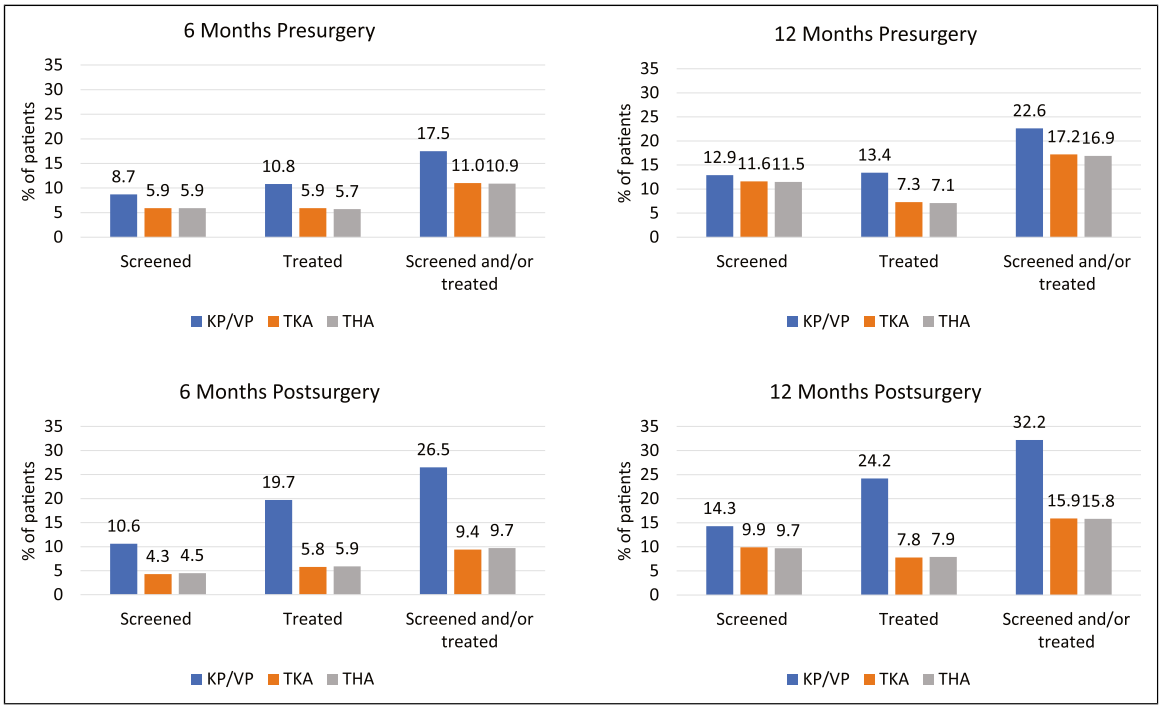

Figure 2. OP Testing and Treatment Rates by Type of Surgery K/V = kyphoplasty/vertebroplasty, THA = total hip arthroplasty, TKA = total knee arthroplasty.

15 001/202 236 (7.4%) received OP treatment. Similar trends were observed across all types of surgeries and for men.

Overall, the rate of testing/treatment following surgery remained low (29 221/251 919 [11.5%]) at 6 months postsurgery. The rate of treatment for men remained the same in the 6-month period after surgery (1668/49 683 [3.4%]) compared with the presurgery period (1122/49 683 [2.3%]), and was slightly higher in the 12-month period following surgery (2115/49 683 [4.3%]). The magnitude of increase in women was larger (8.6% at 6 months postsurgery and 11.2% at 12 months postsurgery).

Among those treated, the majority received antiresorptive agents. Anabolic treatments were used in fewer than five percent of the population overall, mostly in patients undergoing KP/VP (3.2%) compared to THA (.31%) or TKA (.17%). Similar patterns were observed for all treatments 12 months following surgery, with a higher proportion of patients undergoing KP/VP receiving treatment (24.2%) compared to THA (7.9%) or TKA (7.8%).

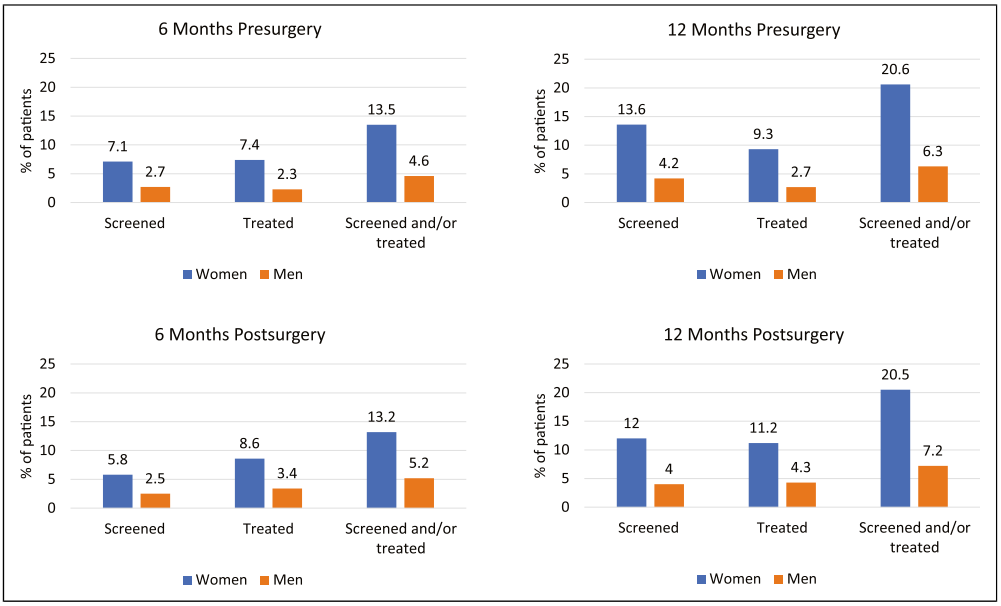

Figure 3. OP Testing and Treatment Rates in Men vs Women.

When OP management in the year prior to elective surgery was evaluated for each procedure by risk category, a higher rate of treatment and/or testing was observed for patients with a diagnosis of OP and at VHRFx (30.8%) compared to those without OP diagnosis (11.5%). Specifically, among patients with OP undergoing KP/VP, 35.1% were treated for OP and/or had a DXA scan. For THA and TKA, the rates of OP treatment and/or testing were 28.9% and 29.1%, respectively. Among patients without an OP diagnosis, 11.4% undergoing KP/VP, 11.2% undergoing THA, and 11.6% undergoing TKA were treated and/or tested for OP 12 months presurgery. Among those without OP but with a fracture in the preceding year, rates of OP treatment and/or testing were 10.2% overall; 11.7% for KP/VP, 6.2% for THA, and 9.8% for TKA.

In the subgroup analyses of women ≥65 years of age (N = 143 835), there was a slightly higher rate of testing and/or treatment in the 6 months prior to an orthopaedic surgery for women ≥65 compared to women <65 (21 163/143 835 [14.7%] vs 6192/58 401 [10.6%]). The screening/treatment rates were higher with a longer observation period. In the 24 months prior to an orthopaedic surgery, rates remained higher for patients ≥65 than for those <65 (49 841/143 835 [34.7.0%] vs 14 860/58 401 [25.4%]). Likewise, in the 24 months following a surgery 48 556/143 835 (33.8%) of patients ≥65 had testing and/or treatment compared with 15 389/58 401 (26.4%) of patients <65.

Regression Modeling Results

For women, already being diagnosed and on treatment for OP when they fractured, or being on medication causing bone loss, significantly predicted OP medication use in the 12 months after orthopaedic surgery ($P < .00051$). Other predictors of OP treatment initiation included rheumatoid arthritis, chronic obstructive pulmonary disease, asthma, and lung or renal transplant. Type 2 diabetes mellitus (T2DM) and obesity were inversely related to the patients' likelihood to get treated in the year following surgery.

Women undergoing THA were more likely to receive treatment if they had a case-qualifying fracture within the 12 months prior to surgery, and those with VP/KP and TKA were more likely continue receiving OP treatment if they were treated prior to their surgery. For men, having a fracture while on an OP medication, taking a medication causing bone loss, or having OP treatment prior to their orthopaedic surgery were also significant predictors of postsurgery OP treatment initiation across all surgeries ($P < .05$).

Discussion

A high proportion of patients undergoing orthopaedic surgery had a history of OP (based on the presence of ≥1 medical inpatient or outpatient preindex claim for OP), and a majority of those were considered to be at VHRFx. Although men are less likely to have a history of OP, a higher proportion of men had a fracture in the year preceding their surgery, suggesting underrecognition of fractures in men as OP related. Patients undergoing KP/VP had a higher prevalence of OP and a higher likelihood to receive OP treatments than patients undergoing THA and TKA. This may reflect a lower recognition of OP in patients undergoing THA and TKA. Having diabetes and obesity were inversely related to the patients' likelihood to

receive treatment in the year following surgery. Although these patients are at risk for impaired or delayed healing due to poor bone quality, they are often considered not to be at risk for fracture due to higher BMD T-score and remain undertreated.

Osteoarthritis (OA) is the most common cause of knee replacements and many hip replacement procedures. Previous studies suggest that, similar to our findings, 43% of patients with OA undergoing TKA also have low bone mass and 23% have OP.[14] For patients undergoing THA or TKA, a higher proportion of those with a history of OP, those at VHRFx, and those with a fracture in the year prior to surgery received OP treatment prior to surgery and in the year following surgery. This may reflect the recognition of a fracture as an important risk factor for complications and periprosthetic fracture (PPFx) after a THA and TKA, prompting better management of OP in these patients.

Early identification and treatment of patients at high risk for fracture has the potential to improve outcomes of orthopaedic surgery and lower the downstream costs associated with revision surgeries, infections, and refractures. A few studies have previously evaluated the management of OP in patients undergoing orthopaedic surgery; however, they either included a small population of patients from a few clinical practice settings or were conducted many years ago, prior to the release of recent clinical practice guidelines emphasizing the importance of bone health management in orthopaedic surgery.[12]

The results of this study are comparable with those reported in several other studies, including a high prevalence of OP in patients with TKA (32.0%). Studies have consistently demonstrated undertreatment of OP in patients undergoing orthopaedic surgery. In a study by Ha et al, the prevalence of OP was 50.0% (53.4% in women and 7.0% in men) for patients undergoing TKA; however, only 15.1% (149/986) of patients had received pharmacological treatment for OP prior to undergoing a primary TKA.[15] In a study by Bernatz et al,[16] an evaluation of 200 medical chart reviews suggested that 25% of patients with TKA or THA meet the criteria to receive OP treatment, but only 5% received treatment in the 6 months before or after surgery. Age, sex, and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) stiffness was associated with OP. In the current study, 29.1% of patients with OP and undergoing TKA received treatment and/or were tested for OP. The higher proportion of treatment in our study may be reflective of different medication capture rates or variations in demographic and clinical risk factors of the patient populations studied. Almost all patients with a diagnosis of OP in our study were also considered to be at VHRFx. The issue of undertreatment is not exclusive to OP patients undergoing surgery. Factors that contribute to undertreatment in patients with OP include side effects associated with antiresorptive agents (ie, GI issues, osteonecrosis of the jaw, and pathological hip fractures) and the high cost of anabolic agents, which makes osteoporosis challenging to manage. Older patients with osteoporosis also often have additional comorbidities with competing risks and may be taking multiple different medications which can negatively impact adherence.[17] Additionally, time constraints in clinical practice, the silent nature of osteoporosis that prevents recognition until a fracture occurs, and insufficient knowledge regarding bone health may also lead to undertreatment.[18] Even after a fracture occurs, the rate of testing and treatment remains low according to the literature, and reduced reimbursement for DXA scans in recent years may have contributed to a reduction in screening as well.[19-21] The objective of the study was to raise awareness regarding the high prevalence of risk factors since many are likely not yet diagnosed or treated.

A recent meta-analysis with pooled data across 11 studies and 3462 patients, with a majority from Asian and Europe countries, suggests that 24.8% of patients undergoing total joint arthroplasty have OP and the proportion is higher in postmenopausal women (38.3%) compared to women overall (29.0%) and men (5.5%).[22] The treatment rate of OP in total joint arthroplasty patients from 5 studies was 32.9% (95% confidence interval [CI]: 15.2%-53.1%) by a random-effects model, which was higher than that observed in the current study, but the data were from globally published studies where clinical practice guidelines and care pathways may be different than in the US.

Limitations and Strengths

The current study findings should be interpreted within the context of several limitations. First, we used administrative claims data which are generated for billing purposes and not for research. There could be errors due to missing data and coding representing diagnoses to be ruled out. Second, Symphony claims data do not provide enrollment information. The presence of a medical or hospital claim in the period of 9 to 14 months before and after index date was used as a proxy for continuous 12-month enrollment. The data was also focused on patients who have OP, limiting fracture interpretations to patients with OP, not general patients who undergo elective surgeries. Third, the PatientSource data used in this project is for patients with either OP diagnosis, OP treatment, or fracture over the time. It did not cover surgical patients without these conditions. The actual rate of OP diagnosis or treatment could be lower if including all surgical patients. Additionally, by definition, patients undergoing KP/VP have vertebral collapse or insufficiency fractures while patients generally undergo elective TKA/THA due to arthritis and degenerative joint disease. This is consistent with our study where 97.3% of THA and 99.9% of TKA patients

compared to 63.1% of KP/VP patients had arthritis. These inherent differences in conditions and their relation to bone health may have impacted comparisons between these populations.

We had data on whether a DXA scan was ordered, but we did not have the data to determine whether patients had low bone density and met treatment criteria for OP treatment initiation. Additionally, the identification of patients with VHRFx was limited by what was available through the claims data and only information on medications that were dispensed is available, but not information on medication use. Therefore, undertreatment may be overestimated or underestimated.

The study has several strengths. First, to our knowledge, it is the largest study to date evaluating the management of OP in orthopaedic surgery. The study was broad, including the most common types of elective surgeries and management by sex and risk were also evaluated. We also evaluated both 6-month and 12-month data to ensure that any late submissions of claims were captured.

Conclusions

A significant proportion of patients undergoing elective orthopaedic surgery had OP and did not receive bone health evaluation and management after their elective surgery, which may contribute to poor outcomes following orthopaedic surgery. Overall, men had a lower rate of testing and/or treatment than women; approximately one-third that of the rate for women. Treatment rates for men changed little from the preindex period through month 12 following surgery treatment. Most women aged ≥65 years lacked evaluation of BMD in the 24 months prior to surgery and the majority remained untreated for OP in the 24 months after surgery. Future research should include the assessment of bone quality and density to further evaluate the management of bone health in orthopaedic surgery. Further, longitudinal evaluation of patients with OP on different care pathways in real-world studies will expand understanding of the potential impact on complications following orthopaedic surgeries.

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Author Contributions

KJJ contributed to the concept and design of the study and data interpretation. SAW contributed to the concept and design of the study, acquisition of data, and data interpretation, and helped draft the work. YW contributed to the concept and design of the study, acquisition of data, and data interpretation. LP contributed to the concept and design of the study and data interpretation. NP contributed to the acquisition of data and data interpretation, and conducted analyses. KS contributed to the data interpretation. BHH contributed to the data interpretation. SVB contributed to the data interpretation. All authors provided critical review and final approval of the publication for submission and agree to be accountable for the work. This publication was created with 100% human content.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: KJJ reports personal fees from Radius Health, Inc. (Radius) and Zimmer, and serves as a board member, owner, officer, or committee member of the American Board of Orthopaedic Surgery, the American Orthopaedic Association, the Orthopaedic Trauma Association, and the Southeastern Fracture Consortium, outside the submitted work. SAW is a former employee of Radius. LP and YW are employees of Radius. NP is an employee of Cobbs Creek Healthcare and is a paid consultant of Radius. KS and BHH have nothing to declare. SVB reports personal fees from Radius and Amgen, serves as a consultant for Solarea Bio, and she is a board member of the Orthopaedic Research Society and member of the Board of Specialties of the American Academy of Orthopaedic Surgery.

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Data Availability Statement

The source data for this study were licensed from a third party, by Radius Health, Inc (Radius). Although we are not permitted to share the licensed data publicly, the same data used in this study are available for others to license by contracting with the database owners. Radius licensed data from Symphony Health, an ICON plc Company, PatientSource, May 1st, 2017 and May 31st, 2020, which included anonymized patient level data from pharmacy claims linked to commercial and Medicare medical claims data. Symphony Health licensing information can be found at www.symphonyhealth.com with the database owners. The authors did

not have any special access privileges that other parties who license the data and contract with Symphony would not have.

Supplemental Material

Supplemental material for this article is available online.

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