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Utilization of Vertebroplasty/Kyphoplasty in the Management of Compression Fractures: National Trends and Predictors of Vertebroplasty/Kyphoplasty

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Objective: The purpose of this study is to examine the utilization of kyphoplasty/vertebroplasty procedures in the management of compression fractures. With the growing elderly population and the associated increase in rates of osteoporosis, vertebral compression fractures have become a daily encounter for spine surgeons. However, there remains a lack of consensus on the optimal management of this patient population.
Methods: A retrospective analysis of 91 million longitudinally followed patients from 2016 to 2019 was performed using the PearlDiver Patient Claims Database. Patients with compression fractures were identified using International Classification of Disease, 10th Revision codes, and a subset of patients who received kyphoplasty/vertebroplasty were identified using Common Procedural Terminology codes. Baseline demographic and clinical data between groups were acquired. Multivariable regression analysis was performed to determine predictors of receiving kyphoplasty/vertebroplasty.
Results: A total of 348,457 patients with compression fractures were identified with 9.2% of patients receiving kyphoplasty/vertebroplasty as their initial treatment. Of these patients, 43.5% underwent additional kyphoplasty/vertebroplasty 30 days after initial intervention. Patients receiving kyphoplasty/vertebroplasty were significantly older (72.2 vs. 67.9, $p < 0.05$), female, obese, had active smoking status and had higher Elixhauser Comorbidity Index scores. Multivariable analysis demonstrated that female sex, smoking status, and obesity were the 3 strongest predictors of receiving kyphoplasty/vertebroplasty (odds ratio, 1.27, 1.24, and 1.14, respectively). The annual rate of kyphoplasty/vertebroplasty did not change significantly (range, 8%–11%).
Conclusion: The majority of vertebral compression fractures are managed nonoperatively. However, certain patient factors such as smoking status, obesity, female sex, older age, osteoporosis, and greater comorbidities are predictors of undergoing kyphoplasty/vertebroplasty.

Keywords: Compression fracture, Kyphoplasty, Vertebroplasty, Osteoporosis

INTRODUCTION

The population of elderly people is increasing rapidly. The percentage of individuals aged 65 and older is expected to double over the next 30 years, and the number of people aged 80 and older expected to triple between 2015 and 2050.[1] As the popu-

lation ages, the incidence of osteoporosis is also increasing. By 2010 United States (US) Census estimates, osteoporosis or low bone mass of the femoral neck or the lumbar spine affected approximately 53.6 million adults over the age of 50. This was based on a 10.3% prevalence of osteoporosis and a 43.9% prevalence of low bone mass.[2] A 2020 estimate approximated a number closer to 61 million elderly individuals in the US with osteoporotic pathology.[3] This condition places these people at higher risk of fragility fractures, especially of the hip, vertebrae, and distal radius.[4]

The most common complication of osteoporosis is vertebral compression fracture (VCF), affecting over 700,000 Americans each year.[5] However, most VCFs go undiagnosed and untreated: nearly 50% of all thoracolumbar VCFs are missed on lateral radiographs, and only about 1/3 of fractures ever come to clinical attention.[6] Furthermore, management trends have shifted over time, with fewer than 30% of patients with a sentinel VCF receiving antiosteoporotic medication in the year following the diagnosis. Ideally, patients presenting with VCFs should be treated for osteoporosis. Patients with sentinel VCF are at a fivefold increased risk of subsequent VCFs.[7]

Management of VCF usually focuses on nonoperative therapy for symptom control including medication, bracing, physical therapy, and injections. Vertebral augmentation including vertebroplasty and kyphoplasty can be considered in patients who do not experience adequate pain relief, though controversy continues to exist surrounding their efficacy in this patient population. The American Academy of Orthopedic Surgeons in 2010 recommended conservative management of neurologically intact patients with VCFs and against vertebroplasty based on 2 randomized controlled trials that were undertaken in 2009. The data looked at patients with either acute or chronic VCF and compared vertebroplasty to a sham procedure; they found no significant improvement in pain reduction, quality of life, or function.[8,9] However, a meta-analysis conducted in 2013 analyzed 6 randomized controlled trials and found that vertebroplasty did in fact provide improved pain relief, quality of life, and functional improvement compared to conservative management.[10] In 2014, a consensus statement was issued from several US and Canadian neurosurgical and radiologic groups supporting consideration of kyphoplasty/vertebroplasty in patient subgroups who are undergoing conservative therapy but are unable to ambulate early, have pain precluding participation in physical therapy, or have adverse reactions to pain medications.[11] A 2023 randomized controlled trial of 80 patients with painful VCFs demonstrated that vertebroplasty provides more effective pain relief and greater quality of life improvement when compared to anesthetic infiltration alone.[12]

With the growing elderly population and associated rates of osteoporosis, the frequency of VCFs has become a daily encounter for spine surgeons. However, there remains a lack of consensus on the optimal management of this patient population. We aim to examine national trends in the utilization of kyphoplasty/vertebroplasty in the management of compression fractures and attempt to elucidate patient factors that led to these procedures.

MATERIALS AND METHODS

After obtaining Institutional Review Board (IRB) approval of Oregon Health & Science University (IRB No. 00024316), we performed a retrospective analysis of compression fracture patients and their rates of kyphoplasty/vertebroplasty using the PearlDiver Inc. database (Pearldiver Technologies, Fort Wayne, IN, USA).[13] This national database consists of 91 million patients randomly selected from all payers except Kaiser and Tricare, longitudinally followed from 2010 to 2020. Patients with compression fractures were identified using International Classification of Disease, 10th Revision (ICD-10) diagnosis codes, while kyphoplasty/vertebroplasty procedures were identified using their respective Common Procedural Terminology (CPT) codes (Table 1). Due to the heterogeneity between ICD-9 and ICD-10 codes, we elected to use only ICD-10 codes. Since ICD-10 codes were introduced around 2015, the patients selected for this study

Table 1. Diagnosis and procedure codes

Code(s)	Description
ICD-10-D-S22000A, ICD-10-D-S22010A, ICD-10-D-S22020A, ICD-10-D-S22030A, ICD-10-D-S22040A, ICD-10-D-S22050A, ICD-10-D-S22060A, ICD-10-D-S22070A, ICD-10-D-S22080A, ICD-10-D-S32000A, ICD-10-D-S32010A, ICD-10-D-S32020A, ICD-10-D-S32030A, ICD-10-D-S32040A, ICD-10-D-S32050A	Compression fracture diagnosis
CPT-22510, CPT-22511, CPT-22520, CPT-22521, CPT-22523, CPT-22524	Vertebroplasty/kyphoplasty procedure

CPT, Common Procedural Terminology; ICD, International Classification of Disease.

were limited to those that had a compression fracture during the years 2016 to 2019. Inclusion criteria consisted of patients with thoracic or lumbar compression fractures between the ages of 18 and 89. We included this range of ages in an attempt to fully encompass the pathology of vertebral fractures. Exclusion criteria consisted of patients with missing data in the variables of interest. Demographic and clinical data, including age, sex, ICD-10 diagnosis codes, CPT codes, Elixhauser Comorbidity Index (ECI), obesity status (body mass index [BMI] > 30 kg/m^2), osteoporosis status, and tobacco use status were obtained through the PearlDiver database. The ECI uses 30 weighted comorbidities to assign a comorbidity burden and can be used to predict the risk of in-hospital mortality and risk of 30-day, all-cause readmission.[14] ECI incorporates disease processes such as congestive heart failure and hypertension, in addition to neurodegenerative disorders and paralysis.

Variables were analyzed for their association with kyphoplasty/vertebroplasty versus medical treatment using univariable chi-square analysis, multiple logistic regressions, and odds ratios. Logistic regression was used to identify factors associated with the treatment method. The model included a dependent variable of undergoing a kyphoplasty/vertebroplasty procedure and predictor variables of ECI and age as continuous variables and obesity, tobacco use, sex, and osteoporosis as categorical variables. Another logistic regression model using the same predictor variables assessed the odds of having a second kyphoplasty/vertebroplasty procedure 30 days after the initial kyphoplasty/vertebroplasty procedure. For analyses, univariate analysis using the chi-square test for comparison of incidence rates and t-test for continuous variables was used. Statistical significance was defined as $p < 0.05$. All statistical analysis was conducted using R ver. 4.2.1 (R Foundation for Statistical Computing, Vienna, Austria) integrated within PearlDiver.

We also elected to divide the cohort into patients aged 64 and younger, and those aged 65 and older in an effort to categorize the different factors affecting the geriatric population. The aforementioned analysis was run separately on these stratified groups.

RESULTS

A total of 348,457 patients with an ICD-10 diagnosis code of compression fracture were identified. Among this patient cohort, the average age was 68.3 ± 14.8 years, the average ECI was 6.6 ± 4.3, and 65% were female. The overall rate of vertebroplasty/kyphoplasty was 9.2% (n = 32,140). Of these patients, 43.5% underwent additional kyphoplasty/vertebroplasty procedures 30 days after initial intervention. Patients receiving kyphoplasty/vertebroplasty were significantly older (72.2 vs. 67.9, $p < 0.05$), female, obese, had active smoking status, and had higher ECI scores. While the absolute number of kyphoplasty/vertebroplasty increased during our study period, the annual rate of kyphoplasty/vertebroplasty showed a decreasing trend due to the relatively greater increase in the number of compression fractures (11% in 2016 to 8% in 2019). This trend, however, was not statistically significant ($p \approx 0.3502$). Two important insights may be gleaned from this finding. First, the rate of compression fractures is increasing and is likely stemming from the growing elderly population in the US.[15] Second, while the majority of compression fractures do not require vertebral augmentation procedures, there is an increase in the absolute case volume of vertebral augmentation across the US with a compound annual growth rate of 5.38%. This finding parallels a recent report on the vertebroplasty and kyphoplasty market, which predicted a compound annual growth rate of 5.6% from 2022 to 2029.[16] With the increasing number of vertebral augmentation procedures, ongoing scientific studies to examine safety and efficacy of these procedures are essential.

Univariable analysis in all patients showed that age, ECI, sex, obesity, and tobacco use were associated with higher rates of vertebroplasty/kyphoplasty. Specifically, patients who underwent vertebroplasty or kyphoplasty were older ($p < 0.001$), had a higher ECI ($p < 0.001$), were more commonly female ($p < 0.001$), had higher rates of obesity ($p < 0.001$), and had higher rates of tobacco use ($p < 0.001$) (Table 2). In the multivariable logistic re-

Table 2. Demographics of patient cohort

Variable	Vertebroplasty/ kyphoplasty (n = 32,140)	Medical treatment (n = 316,317)	p-value
Age (yr)	72.2 ± 9.3	67.9 ± 15.2	< 0.001
ECI	7.1 ± 4.2	6.5 ± 4.3	< 0.001
Sex			< 0.001
Male	9,259 (29)	113,986 (36)	
Female	22,881 (71)	202,328 (64)	
Obesity			< 0.001
Yes	8,230 (26)	72,690 (23)	
No	23,910 (74)	243,627 (77)	
Tobacco use			< 0.001
Yes	6,695 (21)	62,059 (20)	
No	25,445 (79)	254,258 (80)	

Values are presented as mean ± standard deviation or number (%).
ECI, Elixhauser Comorbidity Index.

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Table 3. Multivariate analysis on receiving vertebral augmentation after VCF

Variable	Odds ratio	95% CI	p-value
Obesity	1.19	1.16–1.23	<0.001
Age	1.03	1.02–1.03	<0.001
ECI	1.03	1.02–1.03	<0.001
Female sex	1.21	1.18–1.23	<0.001
Tobacco use	1.24	1.20–1.28	<0.001

VCF, vertebral compression fracture; CI, confidence interval; ECI, Elixhauser Comorbidity Index.

Table 4. Multivariate analysis on patients 64 and under receiving vertebral augmentation after VCF

Variable	Odds ratio	95% CI	p-value
Obesity	1.76	1.66–1.86	<0.001
Age	0.95	0.94–0.95	<0.001
ECI	1.03	1.02–1.03	<0.001
Female sex	1.04	0.98–1.09	0.167
Tobacco use	2.05	1.94–2.17	<0.001
Osteoporosis	4.35	4.07–4.64	<0.001

VCF, vertebral compression fracture; CI, confidence interval; ECI, Elixhauser Comorbidity Index.

Table 5. Multivariate analysis on patients 65 and over receiving vertebral augmentation after VCF

Variable	Odds ratio	95% CI	p-value
Obesity	1.23	1.19–1.27	<0.001
Age	1.07	1.06–1.07	<0.001
ECI	1.00	1.00–1.00	0.004
Female sex	1.28	1.24–1.32	<0.001
Tobacco use	1.14	1.09–1.18	<0.001
Osteoporosis	3.62	3.51–3.74	<0.001

VCF, vertebral compression fracture; CI, confidence interval; ECI, Elixhauser Comorbidity Index.

gression model, age (odds ratio [OR], 1.03; 95% confidence interval [CI], 1.02–1.03, p<0.001), ECI (OR, 1.03; 95% CI, 1.02–1.03, p<0.001), obesity (OR, 1.19; 95% CI, 1.16–1.23, p<0.001), female sex (OR, 1.21; 95% CI, 1.18–1.23, p<0.001), and tobacco use (OR, 1.24; 95% CI, 1.20–1.28, p<0.001) remained significant predictors of kyphoplasty/vertebroplasty (Table 3).

When stratified for age, our analysis produced interesting differences. In patients aged 64 and under, female sex no longer remained a significant predictor of vertebral augmentation (OR, 1.04; 95% CI, 0.98–1.09, p=0.167). A diagnosis of osteoporosis conferred the greatest odds of undergoing kyphoplasty/vertebroplasty (OR, 4.35; 95% CI, 4.07–4.64, p<0.001) (Table 4). Female geriatric patients, aged 65 and older, did indeed exhibit significantly higher odds of undergoing the procedures, with osteoporosis once again emerging as the strongest predictor of procedural intervention (OR, 3.62; 95% CI, 3.51–3.74, p<0.001) (Table 5).

Table 6. Multivariate analysis on multiple vertebroplasty/kyphoplasty procedures after VCF

Variable	Odds ratio	95% CI	p-value
Obesity	1.08	1.02–1.15	0.007
Age	0.98	0.98–0.99	<0.001
ECI	1.02	1.01–1.03	<0.001
Female sex	1.12	1.08–1.17	<0.001
Tobacco use	1.17	1.11–1.24	<0.001

VCF, vertebral compression fracture; CI, confidence interval; ECI, Elixhauser Comorbidity Index.

Table 7. Annual rates of vertebroplasty/kyphoplasty

Year	No. of compression fractures	No. of kyphoplasty/vertebroplasty	Annual kyphoplasty/vertebroplasty rate
2016	63,953	6,808	11%
2017	71,929	7,175	10%
2018	79,120	7,380	9%
2019	93,908	7,966	8%

$\chi^2 \approx 3.298$. $p \approx 0.3502$.

Rates of undergoing a second procedure were associated with age (OR, 0.98; 95% CI, 0.98–0.99, p<0.001), ECI (OR, 1.02; 95% CI, 1.01–1.03, p<0.001), obesity (OR, 1.08; 95% CI, 1.02–1.15, p=0.007), female sex (OR, 1.12; 95% CI, 1.08–1.17, p<0.001), and tobacco use (OR, 1.17; 95% CI, 1.11–1.24, p<0.001) (Table 6). The annual rate of kyphoplasty/vertebroplasty did not change significantly (range, 8%–11%) (Table 7).

DISCUSSION

Nonoperative management of VCF remains the primary treatment of choice, as alluded to by the American Academy of Family Physicians.[17] VCFs tend to have a benign natural history with inherent biomechanical stability and improved pain control over time,[18] rendering surgical treatments largely unnecessary in most cases. Less than 10% of patients with compression fractures found in our database search underwent kyphoplasty/vertebroplasty as their treatment modality. A recent systematic literature review found that 17.5% of patients failed conservative management of

VCF (defined as chronic pain, functional disability, kyphotic deformity, continued compression, reduced quality of life, and subsequent VCF), and presumably required procedural intervention.[18] Risk factors for failing conservative management were previously identified, with about a third of patients failing due to a history of prior VCF.[18] In our analysis, 43.5% of patients with history of VCF received additional kyphoplasty/vertebroplasty after the initial intervention, highlighting again that sentinel VCF is a significant risk factor for further fractures. Importantly however, a 2014 meta-analysis found that vertebroplasty itself did not lead to a higher incidence of subsequent VCFs, unless multiple vertebral levels were treated simultaneously.[7]

Multiple previous studies have noted the relationship between smoking and bone health. Tobacco smoke has a direct effect on bone osteogenesis and angiogenesis, interfering with the RANKL/RANK pathway and leading to an imbalance in bone turnover.[19] In turn, active smokers are at higher risk of osteoporosis and associated fractures. Tobacco smoke indirectly leads to changes in body weight, hormone secretion, and oxidative stress levels which can all affect bone mass.[19] Notably, these effects can be reversed by smoking cessation. Cigarette smokers have a greater than 70% risk of VCF[20] and will likely experience impaired bone healing due to the vasoconstrictive effects of nicotine. Additionally, the ability of hemoglobin to bind to oxygen is reduced by carbon monoxide, and cytochrome c oxidase is inhibited by hydrogen cyanide, limiting aerobic metabolism.[21] Smoking also led to higher short-term recurrent pain following vertebroplasty for VCF[22] and higher rates of nonunion in bone healing,[21] both of which could explain the higher rates of vertebral augmentation of smokers in our study. Tobacco users in our analysis demonstrated 24% increased odds of undergoing vertebroplasty or kyphoplasty following VCF but were not predisposed to undergoing multiple percutaneous procedures. Whether this is due to a change in smoking status, the need for more invasive surgical intervention, or there truly is no relation between smoking and multiple vertebroplasties/kyphoplasties, is unclear due to the limitations of the dataset. Tobacco use is not a short-term effect but rather a long-term predictor of osteoporosis, pain sensitivity, and poor health. Therefore, the interpretation should take into account that the search does not identify remote stopping of tobacco use.

Bone mineral density (BMD) is a known factor involved in the pathogenesis of VCF and an important predictor of sentinel fracture.[20] Females experience progressive bone loss after menopause at which time the bone turnover rate increases and remains elevated. At the age of 50, a woman has a 40% chance of experiencing a VCF throughout her life course.[23] Rates of vertebral and hip fractures are higher in women older than 65 due to both high concentrations of sex hormone-binding globulin and low concentrations of serum estradiol.[24] A prospective case-cohort study of American women aged 65 and older found that a serum estradiol concentration of less than 5 pg/mL was correlated with a greater risk of VCF.[25] It has been suggested that low-dose estrogen replacement therapy could substantially mitigate fracture risk in postmenopausal women. Furthermore, elderly women experience higher rates of hyperthyroidism which can lead to decreased bone strength, muscle strength, and general neuromuscular function. These can all predispose a patient to VCF.[25] Geriatric females demonstrated significantly higher odds of undergoing vertebroplasty/kyphoplasty in our analysis, likely due to higher rates of VCFs in general due to higher osteoporosis prevalence as the female sex was not a significant predictor in the younger cohort, 64 years of age and less.

Many studies have noted that increased BMD is a protective factor against VCF, and obesity increases BMD.[26-29] However, the direct relationship between the risk of fracture and the degree of obesity is not clear. Multiple downstream effects of obesity can influence fracture risk and healing in addition to higher BMD from increased skeletal loading, such as increased impact forces during a fall and greater incidence of diabetes, chronic inflammation, and vascular disease.[30] In fact, the risk of ankle and upper leg fractures was found to be significantly higher in obese women enrolled in the Global Longitudinal study of Osteoporosis in Women, though these women had higher rates of early menopause and more frequent falls than their nonobese counterparts.[31] Similarly, the association between BMI and fracture rate in men was examined using the Osteoporotic Fractures in Men Study and found that most hip and nonspine fractures occurred in obese men.[32] A 2020 study from the United Kingdom Biobank demonstrated a significantly higher VCF incidence in obese men as opposed to normal weight men.[33] This may be due to differences in body fat distribution and the resultant effects of body fat on BMD, as elucidated by a 2013 analysis showing fat mass to have a negative effect on dual-energy x-ray absorptiometry measured BMD.[34] Ultimately, the numerous comorbidities associated with obesity and the metabolic syndrome make it difficult to pinpoint the direct effects of obesity itself on any one disease process as correlated factors can and likely do play major roles in compression fracture pathophysiology.

The incidence of VCF increases with age, as documented by epidemiological studies demonstrating an increase in fracture rate from 8%–13% of women in their 60s to nearly 3–4 times

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that in their 70s.[23] A population-based study conducted over a 20-year time frame found that the incidence of all fractures of both males and females rose with age, with the highest incidence found in the age group greater than 85 years of age. The most common cause for fracture was found to be fall from standing height.[35] As individuals age, cerebral atrophy begins. A significant association has been observed between the volume of brain parenchyma and VCF, possibly because brain degeneration may result in a higher incidence of falls.[36] The mean age of a patient undergoing vertebral augmentation in our analysis was 72.2 years while conservative management was more regularly used for patients with an average age of 67.9 years ($p < 0.001$). As augmentation is commonly reserved for patients who are unable to ambulate early, it follows that this procedure is offered more to elder patients who generally have more limited mobility than their younger counterparts. Interestingly, we found that older age was protective against an additional vertebroplasty/kyphoplasty procedure, which may be attributed to the fact that elder patients may either refuse an additional procedure or may not be offered one due to desires to focus on quality of life and risks outweighing benefits.

As a patient's ECI rises, it is easy to see how their mobility and ability to recover or heal are impaired based on a plethora of physiologic reasons. Additionally, ECI considers obesity as a unique category, which is a significant independent predictor of vertebral augmentation in our population. It may be prudent to assess how the predictive effect of ECI changes if obesity is removed from the index.

This is the first large population study examining the risk factors for vertebral augmentation in patients with VCFs. There are significant limitations to working with a large database like PearlDiver. This study is a retrospective analysis dependent on ICD-10 and CPT coding, particularly accurate coding and documentation of fractures and vertebral augmentation procedures. For instance, if 'compression fracture' was used as the ICD code for a patient with a fracture due to spinal metastases or multiple myeloma instead of 'pathologic fracture,' this would be a confounder as the database would not be able to differentiate the underlying reason for vertebroplasty/kyphoplasty. Additionally, there is no actual BMI value that can be interrogated, only whether a physician has coded the patient for obesity, which limits the ability to stratify the differences in the degrees of obesity. The database does not allow for interpretation of vertebral levels treated; which limits the ability to study reoperation rates. The database also does not allow for interpretation of pain relief in patients who underwent procedures. The retrospective nature of this study limits control over variables studied and prevents an assessment of changes to any variables, such as changes in smoking status throughout the study. Furthermore, the PearlDiver database may not be perfectly generalizable as it represents insurance information from specific payers, though it does incorporate commercial, Medicare, Medicaid, government, and cash payers from all US states and territories.

CONCLUSION

The majority of VCFs are managed nonoperatively. However, certain patient factors such as smoking status, obesity, female sex, older age, and greater comorbidities are predictors of undergoing vertebral augmentation in the form of kyphoplasty or vertebroplasty.

NOTES

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