Secondary Fracture Rate After Vertebral Osteoporotic Compression Fracture Is Decreased by Anti-Osteoporotic Medication but Not Increased by Cement Augmentation

Emily S. Mills, MD, Raymond J. Hah, MD, Zoe Fresquez, BS, Kevin Mertz, BS, Zorica Buser, PhD, MBA, Ram K. Alluri, MD, and Paul A. Anderson, MD

Investigation performed at the Keck School of Medicine, University of Southern California, Los Angeles, California

Background: Painful vertebral osteoporotic compression fractures (OCFs) are often treated with cement augmentation, although controversies exist as to whether or not this increases the secondary fracture risk. Prevention of secondary fracture includes treatment of underlying osteoporosis. The purposes of this study were to determine (1) whether cement augmentation increases the rate of secondary fracture compared with nonoperative management, (2) whether anti-osteoporotic medications reduce the rate of secondary fracture, and (3) the rate of osteoporosis treatment with medications following vertebral OCF.

Methods: The PearlDiver database was queried for all patients with a diagnosis of OCF from 2015 to 2019. Patients were excluded if they were <50 years old, had a diagnosis of spinal neoplasm or infection, or underwent lumbar fusion in the perioperative period. Secondary fracture risk was assessed using univariate and multivariate logistic regression analysis, with kyphoplasty, vertebroplasty, anti-osteoporotic medications, age, gender, and Elixhauser Comorbidity Index as variables.

Results: A total of 36,145 patients were diagnosed with an OCF during the study period. Of those, 25,904 (71.7%) underwent nonoperative management and 10,241 (28.3%) underwent cement augmentation, including 1,556 who underwent vertebroplasty and 8,833 who underwent kyphoplasty. Patients who underwent nonoperative management had a secondary fracture rate of 21.8% following the initial OCF, compared with 14.5% in the vertebroplasty cohort and 18.5% in the kyphoplasty cohort, which was not a significant difference on multivariate analysis. In the entire cohort, 2,833 (7.8%) received anti-osteoporotic medications and 33,312 (92.2%) did not. The rate of secondary fracture was 10.1% in patients who received medications and 21.9% in those who did not, which was a significant difference on multivariate analysis (odds ratio = 1.23, $p < 0.001$).

Conclusions: Cement augmentation did not alter the rate of secondary fracture, whereas anti-osteoporotic medications significantly decreased the risk of subsequent OCF by 19%. Only 7.8% of patients received a prescription for an anti-osteoporotic medication following the initial OCF.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Vertebral osteoporotic compression fractures (OCFs) represent a large burden on the U.S. health-care system. They comprise 27% of all osteoporotic fractures and are the most common osteoporotic fracture among the aging population[1]. In 2015, Medicare spent $658 million on vertebral OCFs, which had an incidence of 102.1 per 10,000 Medicare beneficiaries and a 1-year mortality rate of 21%[2]. The risk of secondary fracture within 12 months of the index event was 15% among these patients[2]. Barton et al. found that 38% of patients with vertebral fracture had secondary fracture within 2 years[3]. Research toward the prevention of OCFs is therefore critical to decrease the strain on the health-care system and patients.

Cement augmentation is a surgical treatment option for vertebral OCF[4]. However, a study by Trout et al. in 2006 showed that patients who underwent vertebroplasty had an increased rate of adjacent-segment fracture[5]. Since then, several randomized controlled trials have shown no difference in the rate of secondary fracture between patients who undergo cement

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/H267).

augmentation and those who receive nonoperative management[6-8]. Meta-analyses of these studies have continued to show no difference in the subsequent fracture rate[9-11]. Nonetheless, controversy still exists as to whether or not cement augmentation increases the secondary fracture risk.

Anti-osteoporotic medications are generally recommended as treatment for OCFs. Guidelines by a number of organizations all recommend secondary fracture prevention including medications for patients with osteoporosis-related spinal fractures[12-14]. Unfortunately, this rarely occurs. Barton et al. reported that 7% of patients were evaluated and treated for osteoporosis after a vertebral OCF[3]. Both antiresorptive and anabolic anti-osteoporotic medications have been shown in multiple randomized controlled trials to reduce the risk of primary and secondary spinal fractures by 40% to 60%[15-18]. In addition, these medications have been shown to decrease the rate of repeat cement augmentation by up to 83%[19-21].

The purposes of this study were therefore to determine (1) whether cement augmentation increases the rate of secondary fracture following a vertebral OCF compared with nonoperative management, (2) whether anti-osteoporotic medications reduce the rate of secondary fracture, and (3) the rate of osteoporosis treatment with medications following a vertebral OCF.

Materials and Methods

The PearlDiver Mariner database is a national database that is commercially available. It contains records on 90 million orthopaedic patients collected from commercial and Medicare insurance claims from 2015 through 2019 in the United States. Both Current Procedural Terminology (CPT) and International Classification of Diseases (ICD) codes can be used to query the database for specific procedures and diagnoses. The database contains de-identified data. Therefore, institutional review board approval was not required to conduct this investigation.

All patients with a diagnosis of a vertebral OCF from 2015 to 2019 were included (Fig. 1). Patients were excluded if they were <50 years old or had a diagnosis of spinal neoplasm or spinal infection in the month prior to diagnosis of the OCF. Additionally, patients who underwent lumbar fusion on the same day or within 3 months following cement augmentation were excluded. Patients were categorized as receiving or not receiving anti-osteoporotic medications within 12 months after the index fracture. Patients were only included in the medication cohort if they received a prescription for the first time following diagnosis of the OCF. Anti-osteoporotic medications including bisphosphonates (both oral and intravenous [IV]), calcitonin, raloxifene, denosumab, and teriparatide were queried using the National Drug Code (NDC). Patients who were prescribed >1 medication were only counted once in the analysis. Patients were divided into those who underwent cement augmentation, defined as either vertebroplasty or kyphoplasty, within 3 months following the initial OCF and those who underwent nonoperative treatment. Patients who underwent >1 vertebroplasty or kyphoplasty were only counted once in the analysis. We then determined the rate of secondary fracture in the year following the initial OCF. Secondary fracture was defined as a new diagnosis of OCF following the initial OCF using only initial encounter ICD-10 codes, as opposed to subsequent encounter and sequela codes. All ICD-10, CPT, and NDC codes utilized can be found in the Appendix.

Statistical analysis was performed using R (version 4.1.0; R Foundation for Statistical Computing). Demographic variables were compared using 2-tailed Student t tests (for continuous variables) or Pearson chi-square tests (for categorical variables). The secondary fracture rate was compared between groups using univariate and multivariate logistic regression analyses. Variables in the multivariate analysis were age, gender, Elixhauser Comorbidity Index (ECI), and whether or not a patient received anti-osteoporotic medications, kyphoplasty, or vertebroplasty. The ECI is a widely used comorbidity index that assesses patients based on 30 different comorbidities[22]. Additionally, the incidence of secondary fracture was assessed separately for antiresorptive and anabolic medications. Variables in these analyses included age, gender, and ECI. All patients who underwent cement augmentation were then grouped, and the secondary fracture risk was assessed with age, gender, ECI, and whether or not a patient received anti-osteoporotic medications as variables. Odds ratios (ORs) with 97.5% confidence intervals (CIs) are reported. A p value of <0.05 was considered significant.

Source of Funding
No funding was received to conduct this study.

Results

Demographics

A total of 36,145 patients were diagnosed with a vertebral OCF during the study period. The largest group of patients were between 75 and 79 years of age, and 79.7% were female (Table I). In the entire cohort, 25,904 (71.7%) of the patients underwent nonoperative management and 10,241 (28.3%) underwent cement augmentation, including 1,556 who underwent vertebroplasty and 8,833 who underwent kyphoplasty (Fig. 1). The latter 2 numbers total more than the total number of patients who underwent cement augmentation, which is likely due to patients who developed a secondary fracture and underwent secondary cement augmentation. The rate of cement augmentation increased over the course of the study period, starting at 25.8% in 2015 and increasing to 28.0% in 2019 (Fig. 2). In the entire cohort, 2,833 (7.8%) of the patients received anti-osteoporotic medications and 33,312 (92.2%) did not. This rate stayed relatively constant over the course of the study period, starting at 8.6% in 2015, dropping to 7.1% in 2018, and ending at 7.7% in 2019 (Fig. 2).

Comparison of Secondary Fracture Risk

Patients who underwent nonoperative management were more likely to be male ($p < 0.001$) and had a higher average ECI ($p < 0.001$). Age and whether or not a patient was prescribed anti-osteoporotic medications were not significantly different between the 2 groups (Table I). Of those who underwent

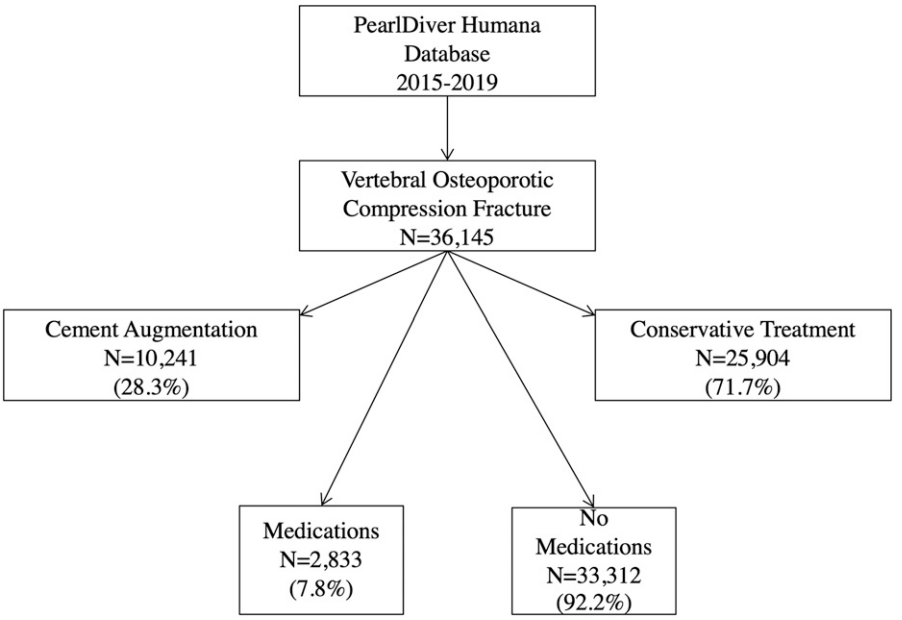

Fig. 1
Study design.

nonoperative treatment, 5,636 (21.8%) developed a secondary fracture following the initial OCF, compared with 225 (14.5%) in the vertebroplasty cohort and 1,635 (18.5%) in the kyphoplasty cohort. On univariate analysis, vertebroplasty and kyphoplasty did not affect the secondary fracture risk (OR = 0.92 [CI = 0.82 to 1.03], p = 0.153, for vertebroplasty; OR = 1.05

TABLE I Demographic Data*

Demographic	Entire Cohort (N = 36,145)	No CA (N = 25,904)	CA (N = 10,241)	P Value
Age in yr *(no.)*				0.5103
50 to 54	741	543	198	
55 to 59	1,541	1,104	437	
60 to 64	2,664	1,933	731	
65 to 69	3,677	2,605	1,072	
70 to 74	5,086	3,607	1,479	
75 to 79	16,208	11,620	4,588	
80 to 84	6,228	4,492	1,736	
Sex *(no. [%])*				<0.001†
Female	28,795 (79.7)	20,912 (80.7)	7,883 (77.0)	
Male	7,350 (20.3)	4,992 (19.3)	2,358 (23.0)	
Year *(no.)*				0.0028†
2015	2,925	2,171	754	
2016	9,493	6,842	2,651	
2017	8,525	6,055	2,470	
2018	8,206	5,800	2,406	
2019	6,996	5,036	1,960	
Medications *(no. [%])*				0.2784
Yes	2,833 (7.8)	2,029 (7.8)	804 (7.9)	
No	33,312 (92.2)	23,875 (92.2)	9,437 (92.1)	
Mean ECI ± SD	6.62 ± 3.94	6.67 ±3.97	6.51 ±3.85	<0.001†

*CA = cement augmentation, ECI = Elixhauser Comorbidity Index, and SD = standard deviation. †Significant.

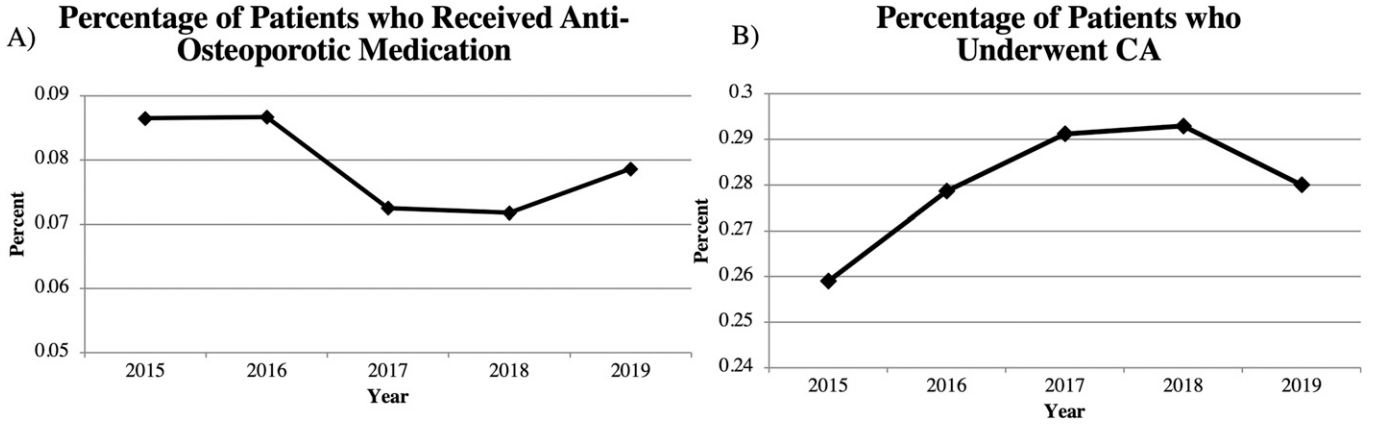

Fig. 2

Fig. 2-A Percentage of patients who received a prescription for anti-osteoporotic medications from 2015 to 2019. **Fig. 2-B** Percentage of patients who underwent cement augmentation (CA) from 2015 to 2019.

[CI = 1.00 to 1.11], p = 0.068, for kyphoplasty). Anti-osteoporotic medications were found to significantly decrease the secondary fracture risk. The secondary fracture rate was 10.1% in patients who received such medications compared with 21.9% in those who did not receive medications (OR = 1.23 [CI = 1.17 to 1.30], p < 0.001). Patients who were younger, were female, and had a higher ECI were also found to have an increased risk of secondary fracture on univariate analysis (Table II).

In the multivariate analysis, vertebroplasty and kyphoplasty continued not to affect secondary fracture risk (OR = 0.92 [CI = 0.82 to 1.03], p = 0.152, for vertebroplasty; OR = 1.06 [CI 1.00 to 1.12], p = 0.060, for kyphoplasty). Patients who did not receive a prescription for anti-osteoporotic medication continued to have an increased risk of secondary fracture (OR = 1.23 [CI = 1.17 to 1.29], p < 0.001). A significantly elevated risk of secondary fracture also persisted in patients who were younger and those with a higher ECI. However, female gender was no longer associated with an increased secondary fracture risk (Table II).

Subanalysis of Antiresorptive Medications

A total of 2,414 patients (6.7%) received antiresorptive medications, including oral bisphosphonates (n = 1,298), IV bisphosphonates (n = 20), denosumab (n = 378), raloxifene (n = 18), and calcitonin (n = 827). Multiple patients were prescribed >1 antiresorptive medication. Patients who received antiresorptive medications had a secondary fracture rate of 10.3%. On univariate analysis, patients who did not receive antiresorptive medications had a significantly increased risk of secondary fracture compared with those who did receive antiresorptive medications (OR = 1.17 [CI = 1.11 to 1.24], p < 0.001). In this analysis, patients who were younger, were female, and had a higher ECI had an increased risk of secondary fracture (Table III).

On multivariate analysis, no prescription for antiresorptive medications remained a significant predictor of increased secondary fracture risk (OR = 1.17 [CI = 1.11 to 1.23], p < 0.001). Again, younger age and a higher ECI were associated with increased secondary fracture risk. However, gender no longer significantly affected the secondary fracture risk on multivariate analysis (Table III).

Subanalysis of Anabolic Medications

Four hundred and nineteen (1.2%) of the patients received a prescription for teriparatide following the initial vertebral OCF.

TABLE II Univariate and Multivariate Analysis of Secondary Fracture Rate in the Entire Cohort*

	Univariate				Multivariate			
		CI				CI		
	OR	2.50%	97.50%	P Value	OR	2.50%	97.50%	P Value
Age, per year	1.00	0.99	1.00	0.015†	1.00	0.99	1.00	0.006†
Male gender	0.93	0.87	0.99	0.018	0.96	0.90	1.03	0.265
ECI	1.01	1.00	1.02	<0.001†	1.01	1.00	1.02	0.001†
No medications	1.23	1.17	1.30	<0.001†	1.23	1.17	1.29	<0.001†
Vertebroplasty	0.92	0.82	1.03	0.153	0.92	0.82	1.03	0.152
Kyphoplasty	1.05	1.00	1.11	0.068	1.06	1.00	1.12	0.060

*OR = odds ratio, CI = confidence interval, and ECI = Elixhauser Comorbidity Index. †Significant.

TABLE III Univariate and Multivariate Analysis of Secondary Fracture Rate in Patients Who Received Antiresorptive Medications Compared with Those Who Did Not Receive Anti-Osteoporotic Medications*

	Univariate				Multivariate			
		CI				CI		
	OR	2.50%	97.50%	P Value	OR	2.50%	97.50%	P Value
Age, per year	1.00	0.99	1.00	0.015†	0.99	0.99	1.00	0.004†
Male gender	0.93	0.87	0.99	0.0178†	0.95	0.89	1.01	0.126
ECI	1.01	1.00	1.02	<0.001†	1.01	1.00	1.02	<0.001†
No anti-osteoporotic medications	1.17	1.11	1.24	<0.001†	1.17	1.11	1.23	<0.001†

*OR = odds ratio, CI = confidence interval, and ECI = Elixhauser Comorbidity Index. †Significant.

Of these, 37 (8.8%) were diagnosed with a secondary fracture. On univariate analysis, patients who were not prescribed anti-osteoporotic medications had a significantly increased risk of secondary fracture compared with those who received a prescription for anabolic medications (OR = 1.32 [CI = 1.05 to 1.65], p = 0.015). Younger age, female gender, and a higher ECI were associated with increased risk of secondary fracture (Table IV).

On multivariate analysis, no prescription for anabolic medications continued to show an association with increased secondary fracture risk (OR = 1.30 [CI = 1.03 to 1.62], p = 0.023). Significance also persisted for the other variables; younger age, female gender, and a higher ECI were associated with increased risk of secondary fracture (Table IV).

Subanalysis of Patients Who Underwent Cement Augmentation

Of the patients who underwent cement augmentation, those who received anti-osteoporotic medications had a secondary fracture rate of 4.9%, compared with 17.6% in those who did not receive medications, which was a significant difference on univariate analysis (OR = 1.32 [CI = 1.19 to 1.46], p < 0.001). Female gender was found to be associated with an increased risk of secondary fracture (p = 0.004). Age and ECI were not found to affect the secondary fracture rate in this analysis (Table V).

On multivariate analysis, the difference in secondary fracture rate between those who received medications and those who did not remained significant (OR = 1.28 [CI = 1.16 to 1.43], p < 0.001). Age, gender, and ECI did not demonstrate an effect on the secondary fracture rate on multivariate analysis in those who underwent cement augmentation (Table V).

Discussion

The current findings support that cement augmentation does not alter rates of subsequent vertebral OCF but anti-osteoporotic medications are protective against secondary fracture. Patients who underwent vertebroplasty and kyphoplasty had a secondary fracture rate of 14.5% and 18.5%, respectively, which was not significantly different from the rate of 21.8% in the nonoperative treatment cohort. Patients who received anti-osteoporotic medications had a secondary fracture rate of 10.1% compared with 21.9% in those who did not receive medications, and they were 19% less likely to have a subsequent OCF on multivariate analysis. Additionally, in our subanalysis of patients who underwent cement augmentation, patients who received anti-osteoporotic medications were 22% less likely to have a secondary fracture than those who did not receive medications. Additionally, we found that younger age and increased ECI were associated with increased secondary fracture risk, at a rate of

TABLE IV Univariate and Multivariate Analysis of Secondary Fracture Rate in Patients Who Received Anabolic Medications Compared with Those Who Did Not Receive Anti-Osteoporotic Medications

	Univariate				Multivariate			
		CI				CI		
	OR	2.50%	97.50%	P Value	OR	2.50%	97.50%	P Value
Age, per year	1.00	0.99	1.00	0.015†	1.00	0.99	1.00	0.011†
Male gender	0.93	0.87	0.99	0.0178†	0.92	0.86	0.98	0.010†
ECI	1.01	1.00	1.02	<0.001†	1.01	1.00	1.02	0.001†
No anti-osteoporotic medications	1.32	1.05	1.65	0.015†	1.30	1.03	1.62	0.023†

†Significant.

TABLE V Univariate and Multivariate Analysis of Secondary Fracture Rate in Patients Who Underwent Cement Augmentation*

	Univariate				Multivariate			
		CI				CI		
	OR	2.50%	97.50%	P Value	OR	2.50%	97.50%	P Value
Age	1.01	1.00	1.01	0.066	1.01	1.00	1.01	0.085
Male gender	0.83	0.73	0.94	0.004†	0.88	0.78	1.00	0.057
ECI	1.01	1.00	1.03	0.080	1.01	1.00	1.03	0.074
No anti-osteoporotic medications	1.32	1.19	1.46	<0.001†	1.28	1.16	1.43	<0.001†

*OR = odds ratio, CI = confidence interval, and ECI = Elixhauser Comorbidity Index. †Significant.

0.5% per year and 1% per unit, respectively. Finally, we found a low rate of osteoporosis treatment, with only 7.8% of patients prescribed anti-osteoporotic medications after a vertebral OCF.

Whether or not cement augmentation alters the rate of secondary fracture has been controversial. Trout et al. reported on 432 patients who underwent vertebroplasty and found that 86 patients (19.9%) had a subsequent fracture. Of those fractures, 41.4% occurred in a vertebra adjacent to the prior vertebroplasty. They concluded that vertebroplasty is associated with adjacent-segment fracture and suggested that this may be because the biomechanical effect of the procedure increases the risk of subsequent fracture[5]. However, the cohort was limited to patients who underwent vertebroplasty, and no control group was included for comparison. Because of this, the findings by Trout et al. should not be interpreted as supporting an increased risk of secondary fracture in patients who undergo vertebroplasty compared with nonoperative management.

Other studies have subsequently evaluated the effect of cement augmentation on secondary fracture rates. In 2009, Buchbinder et al. reported that vertebroplasty to treat painful OCFs did not show a benefit compared with sham surgery with respect to improvement in pain[6]. The secondary fracture rate was also assessed at 6 months as a secondary outcome, and no difference between groups was found. In 2010, a randomized controlled trial of 202 patients by Klazen et al. showed no difference in secondary fracture rate between vertebroplasty and nonoperative treatment[7]. A separate randomized controlled trial of 92 patients by Staples et al. likewise showed no difference in secondary fracture rate between vertebroplasty and placebo treatment at 12 and 24 months[8].

Several meta-analyses have been published, and these likewise showed no difference in secondary fracture rate[9-11]. The largest of these was by Zhang et al., who performed a meta-analysis of 12 randomized controlled trials, clinical controlled trials, and prospective studies[9]. They pooled 1,328 patients; 768 underwent cement augmentation and 560 underwent nonoperative management. No difference in secondary fracture rate between the 2 groups was found. A meta-analysis by Anderson et al. of 5 randomized controlled trials again did not find a difference in secondary fracture risk between vertebroplasty and nonoperative treatment[23]. Despite the increasing evidence that cement augmentation does not increase secondary fracture risk, a recent guideline by the American Association of Clinical Endocrinologists (AACE)[12] does not recommend cement augmentation because of the potential increased risk of adjacent-segment fracture that Trout et al. reported[5]. To our knowledge, our cohort of 36,145 patients is the largest study to date on this topic. No difference in secondary fracture rate was found between those who underwent cement augmentation and those who underwent nonoperative management. Our findings confirm the results from the abovementioned randomized controlled trials and meta-analyses that cement augmentation does not alter the rate of secondary fracture.

Our study also supports the abundance of literature indicating that anti-osteoporotic medications are effective at preventing secondary fracture[24-28]. In a national database study of 79,225 patients in Taiwan, Liang et al. found that patients taking calcium and vitamin D, bisphosphonates, or calcitonin were less likely to undergo a repeat cement augmentation, by 66%, 53%, and 78%, respectively[20]. A similar study of the same database by Kao et al. found that patients who received IV anti-osteoporotic medications were 18% less likely to undergo repeat cement augmentation than those who received oral medications[19]. In the present study, patients were 19% less likely to have a subsequent fracture if they received these medications. Furthermore, when focusing on patients who underwent cement augmentation, we found that those who received anti-osteoporotic medications were 22% less likely to have a secondary fracture.

Additionally, in the subanalyses of the individual medication classes, patients who received antiresorptive medications were 15% less likely to be diagnosed with a secondary vertebral OCF, and patients who received anabolic medications were 23% less likely, compared with those who were not medically treated for osteoporosis. Anabolic medications have previously been compared with antiresorptive medications in the literature. Kendler et al. performed a randomized controlled trial comparing teriparatide to risedronate in postmenopausal women with severe osteoporosis[25]. They found that teriparatide decreased the risk of new vertebral OCFs to a greater extent than risedronate did. It is now the recommendation of the Endocrine Society that

women with severe osteoporosis, particularly those with severe or multiple vertebral OCFs, be treated with teriparatide[29]. Our results further support that anabolic medications decrease the secondary fracture risk, relative to patients who do not receive medical treatment for osteoporosis following vertebral OCFs, to a greater degree than antiresorptive medications do.

Recently, the American Society for Bone and Mineral Research (ASBMR) proposed guidelines for routine medical treatment following hip and spinal fractures in postmenopausal women, in which they recommend that all patients ≥65 years old with a vertebral fracture be offered anti-osteoporotic medications[13]. Unfortunately, only 7.8% of the patients in the present study were prescribed anti-osteoporotic medications, which aligns with previous reports of osteoporosis treatment rates following fragility fractures[2]. Barton et al. found a 7% rate of treatment with antiresorptive medications following a vertebral OCF in their retrospective review of 2,933 patients[3]. A recent international study found that only 20% of patients diagnosed with a fragility fracture, including those of the hip, wrist, humerus, or a vertebra, were correctly treated for osteoporosis[30]. Smith et al. recently reported that 92.3% of patients with pelvic fragility fractures were never prescribed anti-osteoporotic medications, and 41% went on to experience another fracture within 2 years[31]. The poor rates of secondary fracture prevention have led to calls for action, including the "Own the Bone" program of the American Orthopaedic Association and the current recommendations from the ASBMR[13,32]. Considering the burden that fragility fractures place on health-care systems and on patients, it is imperative that we improve our treatment of osteoporosis in patients with known osteoporotic fractures.

There are several limitations to this study. Large database studies are limited by reliance on accurate medical coding and are retrospective in nature. Furthermore, the AACE recently recommended that clinicians consider starting patients with very high fracture risk on IV antiresorptive medications[12]. We were unable to determine if patients who were prescribed IV bisphosphonates had a decreased secondary fracture rate compared with those who were prescribed oral bisphosphonates because that analysis lacked sufficient power. However, this is an important area of further research. Lastly, we were unable to account for anti-osteoporotic medication dosing, duration, and patient compliance.

In conclusion, cement augmentation did not alter the rate of secondary fracture following vertebral OCF. However, anti-osteoporotic medications decreased the risk of secondary fracture by 19%. Unfortunately, there was a low rate of osteoporosis treatment, with only 7.8% of patients prescribed anti-osteoporotic medications. Despite recent efforts to promote evidence-based treatment of osteoporosis, we found that the rate of medical treatment continues to be unacceptably low. Physicians should be aware of this large gap in osteoporosis management, and pathways to increase the initiation of anti-osteoporotic medication following vertebral OCFs should be created and implemented.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/H268). ■

Emily S. Mills, MD[1]
Raymond J. Hah, MD[1]
Zoe Fresquez, BS[1]
Kevin Mertz, BS[1]
Zorica Buser, PhD, MBA[1]
Ram K. Alluri, MD[1]
Paul A. Anderson, MD[2]

[1]Department of Orthopaedic Surgery, Keck School of Medicine, University of Southern California, Los Angeles, California

[2]Department of Orthopedic Surgery & Rehabilitation, University of Wisconsin, Madison, Wisconsin

Email for corresponding author: emily.mills@med.usc.edu

References

1. Burge R, Dawson-Hughes B, Solomon DH, Wong JB, King A, Tosteson A. Incidence and economic burden of osteoporosis-related fractures in the United States, 2005-2025. J Bone Miner Res. 2007 Mar;22(3):465-75.

2. Bazell C, Hansen D, Pelizzari M, Pyenson BS. Medicare cost of osteoporotic fractures. 2019 Sep 11. Accessed 2022 Jan 19. https://www.milliman.com/en/insight/medicare-cost-of-osteoporotic-fractures

3. Barton DW, Behrend CJ, Carmouche JJ. Rates of osteoporosis screening and treatment following vertebral fracture. Spine J. 2019 Mar;19(3):411-7.

4. Goldstein CL, Chutkan NB, Choma TJ, Orr RD. Management of the Elderly With Vertebral Compression Fractures. Neurosurgery. 2015 Oct;77(Suppl 4):S33-45.

5. Trout AT, Kallmes DF, Kaufmann TJ. New fractures after vertebroplasty: adjacent fractures occur significantly sooner. AJNR Am J Neuroradiol. 2006 Jan;27(1):217-23.

6. Buchbinder R, Osborne RH, Ebeling PR, Wark JD, Mitchell P, Wriedt C, Graves S, Staples MP, Murphy B. A randomized trial of vertebroplasty for painful osteoporotic vertebral fractures. N Engl J Med. 2009 Aug 6;361(6):557-68.

7. Klazen CAH, Venmans A, de Vries J, van Rooij WJ, Jansen FH, Blonk MC, Lohle PN, Juttmann JR, Buskens E, van Everdingen KJ, Muller A, Fransen H, Elgersma OE, Mali WP, Verhaar HJ. Percutaneous vertebroplasty is not a risk factor for new osteoporotic compression fractures: results from VERTOS II. AJNR Am J Neuroradiol. 2010 Sep;31(8):1447-50.

8. Staples MP, Howe BM, Ringler MD, Mitchell P, Wriedt CH, Wark JD, Ebeling PR, Osborne RH, Kallmes DF, Buchbinder R. New vertebral fractures after vertebroplasty: 2-year results from a randomised controlled trial. Arch Osteoporos. 2015;10:229.

9. Zhang H, Xu C, Zhang T, Gao Z, Zhang T. Does Percutaneous Vertebroplasty or Balloon Kyphoplasty for Osteoporotic Vertebral Compression Fractures Increase the Incidence of New Vertebral Fractures? A Meta-Analysis. Pain Physician. 2017 Jan-Feb;20(1):E13-28.

10. Li HM, Zhang RJ, Gao H, Jia CY, Zhang JX, Dong FL, Shen CL. New vertebral fractures after osteoporotic vertebral compression fracture between balloon kyphoplasty and nonsurgical treatment PRISMA. Medicine (Baltimore). 2018 Oct;97(40):e12666.

11. Chen Z, Song C, Lin H, Sun J, Liu W. Does prophylactic vertebral augmentation reduce the refracture rate in osteoporotic vertebral fracture patients: a meta-analysis. Eur Spine J. 2021 Sep;30(9):2691-7.

12. Camacho PM, Petak SM, Binkley N, Diab DL, Eldeiry LS, Farooki A, Harris ST, Hurley DL, Kelly J, Lewiecki EM, Pessah-Pollack R, McClung M, Wimalawansa SJ, Watts NB. AMERICAN ASSOCIATION OF CLINICAL ENDOCRINOLOGISTS/AMERICAN COLLEGE OF ENDOCRINOLOGY CLINICAL PRACTICE GUIDELINES FOR THE DIAGNOSIS AND TREATMENT OF POSTMENOPAUSAL OSTEOPOROSIS-2020 UPDATE. Endocr Pract. 2020 May;26(Suppl 1):1-46.

13. Conley RB, Adib G, Adler RA, Åkesson KE, Alexander IM, Amenta KC, Blank RD, Brox WT, Carmody EE, Chapman-Novakofski K, Clarke BL, Cody KM, Cooper C, Crandall CJ, Dirschl DR, Eagen TJ, Elderkin AL, Fujita M, Greenspan SL, Halbout P, Hochberg MC, Javaid M, Jeray KJ, Kearns AE, King T, Koinis TF, Koontz JS, Kužma M, Lindsey C, Lorentzon M, Lyritis GP, Michaud LB, Miciano A, Morin SN, Mujahid N, Napoli N, Olenginski TP, Puzas JE, Rizou S, Rosen CJ, Saag K, Thompson E, Tosi LL, Tracer H, Khosla S, Kiel DP. Secondary Fracture Prevention: Consensus Clinical Recommendations From a Multistakeholder Coalition. Orthop Nurs. 2020 May/Jun;39(3):145-61.

14. Cosman F, de Beur SJ, LeBoff MS, Lewiecki EM, Tanner B, Randall S, Lindsay R; National Osteoporosis Foundation. Clinician's Guide to Prevention and Treatment of Osteoporosis. Osteoporos Int. 2014 Oct;25(10):2359-81.

15. Lindsay R, Nieves J, Formica C, Henneman E, Woelfert L, Shen V, Dempster D, Cosman F. Randomised controlled study of effect of parathyroid hormone on vertebral-bone mass and fracture incidence among postmenopausal women on oestrogen with osteoporosis. Lancet. 1997 Aug 23;350(9077):550-5.

16. Greenspan SL, Bone HG, Ettinger MP, Hanley DA, Lindsay R, Zanchetta JR, Blosch CM, Mathisen AL, Morris SA, Marriott TB; Treatment of Osteoporosis with Parathyroid Hormone Study Group. Effect of recombinant human parathyroid hormone (1-84) on vertebral fracture and bone mineral density in postmenopausal women with osteoporosis: a randomized trial. Ann Intern Med. 2007 Mar 6;146(5):326-39.

17. Nakano T, Shiraki M, Sugimoto T, Kishimoto H, Ito M, Fukunaga M, Hagino H, Sone T, Kuroda T, Nakamura T. Once-weekly teriparatide reduces the risk of vertebral fracture in patients with various fracture risks: subgroup analysis of the Teriparatide Once-Weekly Efficacy Research (TOWER) trial. J Bone Miner Metab. 2014 Jul;32(4):441-6.

18. Silverman SL, Christiansen C, Genant HK, Vukicevic S, Zanchetta JR, de Villiers TJ, Constantine GD, Chines AA. Efficacy of bazedoxifene in reducing new vertebral fracture risk in postmenopausal women with osteoporosis: results from a 3-year, randomized, placebo-, and active-controlled clinical trial. J Bone Miner Res. 2008 Dec;23(12):1923-34.

19. Kao FC, Hsu YC, Chen TS, Tu YK, Liu PH. Effects of Injected Antiosteoporotic Medication Versus Oral Bisphosphonates on Rates of Repeated Vertebroplasty or Kyphoplasty. Clin Ther. 2020 Jun;42(6):1087-1098.e2.

20. Liang CL, Wang HK, Syu FK, Wang KW, Lu K, Liliang PC. Repeated vertebral augmentation for new vertebral compression fractures of postvertebral augmentation patients: a nationwide cohort study. Clin Interv Aging. 2015 Mar 27;10:635-42.

21. Tang B, Zeng H, Hu S, Liu K, Wu L, Shi X. Percutaneous Vertebroplasty Combined with Zoledronic Acid in Treatment and Prevention of Osteoporotic Vertebral Compression Fractures: A Systematic Review and Meta-Analysis of Comparative Studies. World Neurosurg. 2022 Jan;157:75-87.

22. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. Med Care. 1998 Jan;36(1):8-27.

23. Anderson PA, Froyshteter AB, Tontz WL Jr. Meta-analysis of vertebral augmentation compared with conservative treatment for osteoporotic spinal fractures. J Bone Miner Res. 2013 Feb;28(2):372-82.

24. Saag KG, Petersen J, Brandi ML, Karaplis AC, Lorentzon M, Thomas T, Maddox J, Fan M, Meisner PD, Grauer A. Romosozumab or Alendronate for Fracture Prevention in Women with Osteoporosis. N Engl J Med. 2017 Oct 12;377(15):1417-27.

25. Kendler DL, Marin F, Zerbini CAF, Russo LA, Greenspan SL, Zikan V, Bagur A, Malouf-Sierra J, Lakatos P, Fahrleitner-Pammer A, Lespessailles E, Minisola S, Body JJ, Geusens P, Möricke R, López-Romero P. Effects of teriparatide and risedronate on new fractures in post-menopausal women with severe osteoporosis (VERO): a multicentre, double-blind, double-dummy, randomised controlled trial. Lancet. 2018 Jan 20;391(10117):230-40.

26. Simpson EL, Martyn-St James M, Hamilton J, Wong R, Gittoes N, Selby P, Davis S. Clinical effectiveness of denosumab, raloxifene, romosozumab, and teriparatide for the prevention of osteoporotic fragility fractures: A systematic review and network meta-analysis. Bone. 2020 Jan;130:115081.

27. Degli Esposti L, Girardi A, Saragoni S, Sella S, Andretta M, Rossini M, Giannini S; on the behalf of the Study group. Use of antiosteoporotic drugs and calcium/vitamin D in patients with fragility fractures: impact on re-fracture and mortality risk. Endocrine. 2019 May;64(2):367-77.

28. Malik AT, Retchin S, Phillips FM, Xu W, Peters K, Yu E, Khan SN. Declining trend in osteoporosis management and screening following vertebral compression fractures - a national analysis of commercial insurance and Medicare advantage beneficiaries. Spine J. 2020 Apr;20(4):538-46.

29. Eastell R, Rosen CJ, Black DM, Cheung AM, Murad MH, Shoback D. Pharmacological Management of Osteoporosis in Postmenopausal Women: An Endocrine Society* Clinical Practice Guideline. J Clin Endocrinol Metab. 2019 May 1;104(5):1595-1622.

30. Malle O, Borgstroem F, Fahrleitner-Pammer A, Svedbom A, Dimai SV, Dimai HP. Mind the gap: Incidence of osteoporosis treatment after an osteoporotic fracture - results of the Austrian branch of the International Costs and Utilities Related to Osteoporotic Fractures Study (ICUROS). Bone. 2021 Jan;142:115071.

31. Smith CT, Barton DW, Piple AS, Carmouche JJ. Pelvic Fragility Fractures: An Opportunity to Improve the Undertreatment of Osteoporosis. J Bone Joint Surg Am. 2021 Feb 3;103(3):213-8.

32. Anderson PA, Jeray KJ, Lane JM, Binkley NC. Bone Health Optimization: Beyond Own the Bone: AOA Critical Issues. J Bone Joint Surg Am. 2019 Aug 7;101(15):1413-9.