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ORIGINAL RESEARCH

Predictors of Vertebroplasty Selection in Older Adults with Osteoporotic Vertebral Compression Fractures: A Real-World Cohort Study

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Video Abstract

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Purpose: The aim of the study was to identify demographic, clinical, and institutional predictors influencing the selection of percutaneous vertebroplasty (PVP) versus conservative management in older adults with osteoporotic vertebral compression fractures (OVCFs).

Patients and Methods: We conducted a retrospective cohort study using the Kaohsiung Medical University Hospital Research Database, including 1688 patients aged ≥50 years hospitalized for OVCFs (2018–2022). Patients were categorized into PVP (n = 385) and conservative management (n = 1,303) groups. Independent predictors of treatment selection were identified using multivariable logistic regression.

Results: Significant predictors of vertebroplasty selection included advanced age (≥85 years), severe pain (VAS 8–10), congestive heart failure, diabetes mellitus, and analgesic usage, while a higher comorbidity burden (CCI ≥2) reduced the likelihood of receiving PVP. Regional hospitals were more likely than medical centers to perform vertebroplasty.

Conclusion: Patient age, pain severity, specific comorbidities, analgesic requirements, and institutional factors significantly influenced treatment selection for OVCFs. These findings underscore the need for individualized, risk-adapted strategies. Given the retrospective design, causal inferences should be interpreted with caution.

Keywords: spinal augmentation, bone fragility, healthcare utilization, analgesic outcomes, geriatric orthopedics, risk factors

Introduction

Osteoporotic vertebral compression fractures (OVCFs) affect over 1.4 million individuals annually worldwide, and the incidence is expected to increase by 50% by 2035 owing to aging populations.[1,2] These fractures are associated with acute pain, functional impairment, decreased quality of life, and increased mortality, with an increase in age-adjusted death rates up to 2.7 times in affected patients.[3–5] Management of OVCFs includes conservative treatment and percutaneous vertebral augmentation techniques,[6] primarily vertebroplasty (PVP) and percutaneous balloon kyphoplasty (PKP).[7–9] The aim of kyphoplasty, which involves balloon inflation before cement injection, is to restore vertebral height and reduce kyphotic deformity, demonstrating favorable pain and function outcomes in selected patients compared with vertebroplasty or conservative care.[10–12] Recent meta-analyses and multicenter trials have shown comparable safety and efficacy profiles between PVP and PKP, though cost, availability, and operator expertise may influence selection.

Despite their clinical utility, the indications, cost-effectiveness, and safety profiles of vertebral augmentation remain controversial. Two landmark sham-controlled trials in 2009 challenged the efficacy of PVP,[13,14] whereas later

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randomized studies (VERTOS II, VAPOUR) revealed significant benefits in appropriately selected patients.[15,16] These conflicting findings have led to discrepant international guidelines, reflecting differences in evidence thresholds, health policy frameworks, and procedural expertise across healthcare systems.[17–20] Furthermore, vertebral augmentation practices vary substantially between regions and institutions, influenced by hospital level, reimbursement systems, and physician specialty preferences.[21,22] For instance, procedural rates are higher in community and regional hospitals than in academic centers, suggesting that local infrastructure and patient access play important roles.[23]

At the same time, patient-centered outcomes—such as pain relief, mobility restoration, and prevention of functional decline—are increasingly prioritized in treatment selection.[24,25] However, the interplay between individual clinical profiles (eg, age, comorbidities, fracture characteristics), institutional factors, and health system constraints remains poorly characterized in real-world settings. Globally, the variability in vertebral augmentation utilization highlights the absence of unified, evidence-based decision frameworks. Understanding how clinical and system-level factors shape procedural decisions may facilitate the development of decision-support tools and guideline harmonization. Accordingly, we conducted a retrospective cohort study using electronic medical records from a multi-institutional healthcare system in Southern Taiwan. This study specifically addresses the knowledge gap regarding real-world determinants of vertebroplasty versus conservative management selection. In addition, how demographic, clinical, and institutional variables inform treatment decisions was also explored. Our findings provide a data-driven foundation for refining clinical decision-making and developing equitable, evidence-based care models for OVCF management.

Materials and Methods

Data Source

In this retrospective cohort study, we used data from the Kaohsiung Medical University Hospital Research Database (KMUHRD), which includes electronic medical records from a medical center and two regional hospitals within the Kaohsiung Medical University health system in Southern Taiwan. The dataset contained patient demographics, diagnoses, surgical codes, inpatient and outpatient records, prescription data, and healthcare costs. Diagnoses were identified using the International Classification of Diseases (ICD)-9-CM or ICD-10-CM coding systems, and medications were confirmed using the Anatomical Therapeutic Chemical classification.

Inclusion and Exclusion Criteria

We included patients aged ≥ 50 years who were newly hospitalized for a primary diagnosis of OVCF between January 1, 2018, and December 31, 2022. Vertebroplasty procedures were identified using the ICD-10 Procedure Coding System (see Table 1). The first OVCF hospitalization during this period was defined as the index hospitalization.

Table 1 Identified Diagnosis and Procedure Code

ICD-10-CM Code	Description
Thoracic vertebra S22.000A, S22.010A, S22.020A, S22.030A, S22.040A, S22.050A, S22.060A, S22.070A, S22.080A **Lumbar vertebra** S32.000A, S32.010A, S32.020A, S32.030A, S32.040A, S32.050A	Vertebral Compression fracture diagnosis
Osteoporosis M81.0 M81.8	Age-related/other osteoporosis without current pathological fracture
ICD-10-PCS 0PU43JZ 0QU03JZ	Percutaneous vertebroplasty

Abbreviations: ICD-10-CM, International Classification of Diseases, 10th Revision; ICD-10-PCS, ICD-10 Procedure Coding System.

Patients were excluded if they were younger than 50 years, had high-energy trauma, prior spinal surgery, vertebral burst or pathological fractures, neurological deficits, or insufficient imaging data, or were lost to follow-up.

Pain Assessment and Clinical Variables

Pain intensity was measured at admission using the Visual Analog Scale (VAS), ranging from 0 (no pain) to 10 (worst pain). Demographic and clinical variables extracted included age, sex, BMI, fracture site, Charlson Comorbidity Index (CCI), and comorbidities (acute myocardial infarction, congestive heart failure, diabetes, cerebrovascular disease, renal disease, and hypertension). Pain-management strategies during hospitalization and hospital level (medical center vs regional hospital) were also recorded.

Handling of Missing Data and Sample Size Justification

Cases with incomplete demographic or clinical information were excluded from analysis to ensure data integrity. The final sample size (n = 1,688) provided adequate power (> 0.80) to detect moderate effect sizes in logistic regression, consistent with Cohen's (1988) standards.

Statistical Analysis

Continuous variables were presented as mean ± standard deviation, and categorical variables as counts and percentages (%). Inter-group differences were assessed using Student's *t*-test and Pearson's χ^2-test, as appropriate. Independent predictors of PVP were determined using multivariable logistic regression. Results were expressed as adjusted odds ratios (aORs) with 95% confidence intervals (CIs). Statistical significance was defined as $p < 0.05$ (two-tailed). All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA).

Methodological Limitations

Given its retrospective design and reliance on a single institutional database, potential selection bias and limited generalizability are acknowledged. Furthermore, radiological and socioeconomic variables were unavailable, and pain assessment relied on a single baseline VAS score. These constraints were considered when interpreting the study findings.

Results

Overall, 1,688 patients diagnosed with OVCFs were analyzed, of whom 385 (22.8%) underwent percutaneous vertebroplasty (PVP) and 1,303 (77.2%) received conservative treatment.

Demographic and Institutional Characteristics

Patients in the vertebroplasty group were significantly older than those managed conservatively (mean age = 76.8 ± 9.8 vs 74.3 ± 9.3 years; $p < 0.001$), and a higher proportion were aged ≥ 85 years (22.1% vs 13.6%). Procedures were performed more frequently in regional hospitals (38.9%) than in medical centers (26.0%) ($p < 0.001$), whereas sex distribution and fracture level (thoracic vs lumbar) showed no significant differences (Table 2).

Comorbidities and Clinical Profiles

Acute myocardial infarction (6.8% vs 2.2%; $p < 0.001$) and congestive heart failure (16.6% vs 6.1%; $p < 0.001$) were more prevalent among vertebroplasty recipients. Other comorbidities, including diabetes, cerebrovascular disease, renal impairment, and hypertension, did not significantly differ.

The mean CCI was similar between groups (1.03 vs 1.12; $p = 0.35$); nonetheless, patients with higher comorbidity burden (CCI ≥ 2) were less likely to receive vertebroplasty, suggesting clinical selection against high-risk profiles (Table 2).

Pain Severity and Management

Baseline pain scores were higher among patients who underwent vertebroplasty (VAS = 4.04 ± 1.96 vs 3.68 ± 1.62; $p < 0.001$), with severe pain (VAS 8–10) reported by 7.0% vs 3.4% of conservatively treated patients ($p = 0.0015$). Analgesic

Table 2 Baseline Characteristics of Patients with Osteoporotic Vertebral Compression Fractures, Stratified by Treatment Strategy

Clinical Characteristics	Percutaneous Vertebroplasty (N=385)		Conservative Treatment (N=1,303)		p-value
	N	%	N	%	
Fracture site					
Thoracic	128	33.25	427	32.77	0.8613
Lumbar	257	66.75	876	67.23	
Hospital level					
Medical center	235	61.04	964	73.98	<0.0001
Regional hospital	150	38.96	339	26.02	
Age (years), mean ± SD	76.77	9.78	74.29	9.30	<0.0001
Age (overall)					
50–64	51	13.25	192	14.74	<0.0001
65–74	101	26.23	463	35.53	
75–79	62	16.10	251	19.26	
80–84	86	22.34	220	16.88	
≥85	85	22.08	177	13.58	
Sex					
Male	74	19.22	255	19.57	0.8791
Female	311	80.78	1048	80.43	
BMI, mean ± SD	24.08	3.85	24.31	4.31	0.3381
Comorbidity					
Acute myocardial infarction	26	6.75	28	2.15	<0.0001
Congestive heart failure	64	16.62	79	6.06	<0.0001
Peripheral vascular disease	5	1.30	19	1.46	0.8164
Cerebral vascular accident	35	9.09	97	7.44	0.2904
Diabetes mellitus	58	15.06	161	12.36	0.1646
Renal disease	34	8.83	120	9.21	0.8208
Essential (primary) hypertension	127	32.99	387	29.70	0.2183
CCI, Mean ± SD	1.03	1.57	1.12	1.75	0.3529
CCI					
0	222	57.66	733	56.25	0.7208
1	53	13.77	201	15.43	
≥2	110	28.57	369	28.32	

Abbreviations: BMI, body mass index; CCI, Charlson Comorbidity Index; VAS, visual analog scale.

Table 3 Initial Pain Severity and Pain Treatment in Patients with Osteoporotic Vertebral Compression Fractures

Clinical Characteristics	Percutaneous Vertebroplasty (N=385)		Conservative Treatment (N=1,303)		p-value
	N	%	N	%	
Initial VAS score, mean ± SD	4.04	1.96	3.68	1.62	0.0008
Initial VAS score (score)					
1–3	196	50.91	620	47.58	0.0015
4–7	162	42.08	639	49.04	
8–10	27	7.01	44	3.38	
Pain treatment					
No	4	1.04	126	9.67	<0.0001
Yes	381	98.96	1177	90.33	

Abbreviation: VAS, visual analog scale.

use was almost universal among the PVP group (98.9% vs 90.3%; p < 0.001) (Table 3). However, the magnitude of this association (aOR = 8.04, 95% CI 2.90–22.33) may partly reflect confounding by indication or reverse causality, as patients receiving more intensive analgesic therapy likely represent those with refractory pain prompting procedural intervention.[17,26]

Predictors of Vertebroplasty

Multivariable logistic regression showed that advanced age ≥ 85 years (aOR = 2.24, 95% CI 1.40–3.57), treatment at regional hospitals (aOR = 1.63, 95% CI 1.24–2.14), congestive heart failure (aOR = 2.74, 95% CI 1.83–4.11), diabetes mellitus (aOR = 1.54, 95% CI 1.02–2.34), severe pain (VAS 8–10) (aOR = 2.85, 95% CI 1.55–5.26) and pain treatment (aOR = 8.04, 95% CI: 2.90–22.33; p < 0.0001) were independent predictors (Table 4).

Table 4 Univariable and Multivariable Logistic Regression Analyses of Factors Associated with Receiving Percutaneous Vertebroplasty

	Univariable			Multivariable		
	OR	95% CI	p-value	OR	95% CI	p-value
Fracture site						
Thoracic	1.00			1.00		
Lumbar	0.98	0.77–1.25	0.8610	0.95	0.73–1.26	0.7399
Hospital level						
Medical center	1.00			1.00		
Regional hospital	1.82**	1.43–2.31	<0.0001	1.63*	1.24–2.14	0.0005
Age (overall)						
50–64	1.00			1.00		
65–74	0.82	0.56–1.20	0.3051	0.93	0.61–1.40	0.7168
75–79	0.93	0.61–1.41	0.7318	0.99	0.62–1.58	0.9792

(*Continued*)

Table 4 (Continued).

	Univariable			Multivariable		
	OR	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
80–84	1.47	0.99–2.19	0.0563	1.50	0.95–2.35	0.0804
≧85	1.81*	1.21–2.71	0.0040	2.24*	1.40–3.57	0.0007
Sex						
Male	1.00			1.00		
Female	1.02	0.77–1.36	0.8796	1.14	0.82–1.58	0.4366
BMI	0.99	0.96–1.02	0.3639	0.99	0.96–1.02	0.5706
Comorbidity						
Acute myocardial infarction	3.30**	1.91–5.70	<0.0001	1.87	1.00–3.50	0.0502
Congestive heart failure	3.09**	2.17–4.39	<0.0001	2.74**	1.83–4.11	<0.0001
Peripheral vascular disease	0.89	0.33–2.40	0.8165	0.83	0.28–2.41	0.7258
Cerebral vascular accident	1.24	0.83–1.86	0.2911	1.56	0.97–2.51	0.0665
Diabetes mellitus	1.26	0.91–1.74	0.1652	1.54*	1.02–2.34	0.0423
Renal disease	0.96	0.64–1.42	0.8226	0.77	0.46–1.27	0.3025
Essential (primary) hypertension	1.17	0.91–1.49	0.2185	0.92	0.67–1.26	0.5975
CCI						
0	1.00			1.00		
1	0.87	0.62–1.22	0.4215	0.66	0.44–1.00	0.0520
≥2	0.98	0.76–1.28	0.9051	0.64*	0.43–0.96	0.0311
Initial VAS score						
1~3	1.00			1.00		
4~7	0.80	0.63–1.02	0.0664	0.94	0.72–1.22	0.6305
8~10	1.94*	1.17–3.22	0.0101	2.85*	1.55–5.26	0.0008
Pain treatment						
No	1.00			1.00		
Yes	10.20**	3.74–27.78	<0.0001	8.04**	2.90–22.33	<0.0001

Note: *P<0.05, **P<0.0001.
Abbreviations: BMI, body mass index; CCI, Charlson Comorbidity Index; CI, confidence interval; OR, odds ratio; VAS, visual analog scale.

Conversely, CCI ≥ 2 was an independent predictor of lower odds of undergoing PVP (aOR = 0.64, 95% CI 0.43–0.96), reinforcing the tendency to avoid invasive intervention in medically complex patients (Figure 1). Kyphoplasty represents an alternative vertebral augmentation procedure; nevertheless, it was not included because it is rarely performed or reimbursed under Taiwan's National Health Insurance system, and no eligible cases were recorded in the dataset.[19,27] The analysis thus reflects real-world utilization patterns within the studied healthcare system. Given the retrospective design and lack of radiological and socioeconomic data, these associations should be interpreted as hypothesis-generating and may guide future prospective validation.

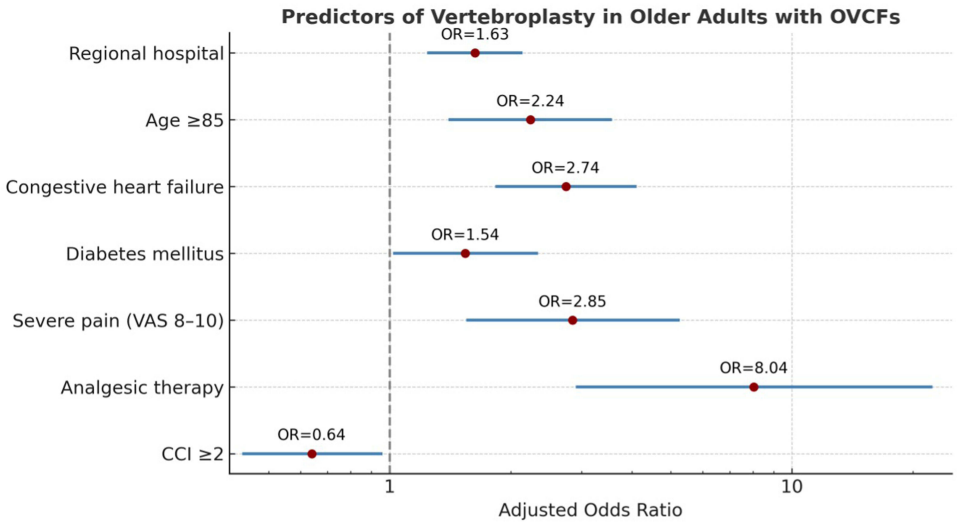

Figure 1 Adjusted odds ratios (aOR) with 95% confidence intervals for predictors of vertebroplasty in older adults with osteoporotic vertebral compression fractures. Significant predictors include hospital level, age ≥85, congestive heart failure, diabetes, severe pain, and use of analgesics. Higher comorbidity burden (CCI ≥2) was associated with lower odds of receiving vertebroplasty. Red dots represent aORs; blue lines indicate 95% CIs.

Discussion

Overview of Key Findings and Clinical Relevance

Our study of 1,688 older adults with OVCFs revealed that treatment selection between PVP and conservative management is influenced by multifactorial determinants spanning patient age, comorbidities, pain severity, analgesic use, and institutional characteristics. These results align with those of prior observational studies showing that decision-making in vertebral augmentation is shaped not only by pain relief potential but also by frailty risk, access to interventional resources, and physician preference.[13,22]

The higher likelihood of vertebroplasty among patients aged ≥85 years suggests that clinicians may prioritize early mobilization to reduce immobilization-related complications—such as pneumonia and thromboembolism—outweighing procedural risk.[12,18] This finding supports recent evidence promoting functional recovery-based selection rather than chronological age alone.

Institutional and System-Level Determinants

Vertebroplasty was performed more frequently in regional hospitals than in academic centers, an inverse diffusion pattern that reflects health system dynamics rather than procedural novelty. Regional hospitals may adopt PVP more widely because of limited rehabilitation infrastructure, shorter expected hospital stays, and fewer restrictions in local reimbursement frameworks.[28,29] In contrast, academic centers may be more conservative, influenced by early sham-controlled trials questioning efficacy.[14,15] This institutional variation echoes findings from international registries where procedure rates vary up to threefold by region and hospital type, underscoring the need for standardized, evidence-based clinical pathways.[23]

Pain Severity, Comorbidities, and Clinical Implications

Pain-related variables were the most powerful predictors of vertebroplasty. Severe pain (VAS 8–10) and concurrent analgesic therapy were strongly associated with procedural selection.However, the observed association between analgesic use and vertebroplasty (aOR = 8.04) likely reflects confounding by indication—patients with refractory pain are inherently more likely to receive procedural intervention—rather than a purely causal relationship. Similar trends were observed in VERTOS IV and VAPOUR, where baseline pain intensity influenced treatment assignment.[16,26] Nonetheless, this relationship should be cautiously interpreted, as it highlights an intrinsic selection bias in retrospective datasets.

Specific comorbidities, including congestive heart failure and diabetes, were associated with higher PVP rates, possibly reflecting physicians' preference for rapid mobilization in patients at risk of cardiopulmonary deconditioning or metabolic instability.[30,31] Conversely, a higher overall comorbidity burden (CCI $\geq$ 2) predicted lower intervention likelihood, suggesting that clinicians weigh procedural benefits against cumulative risk—an observation consistent with prior findings.[32] This paradox reflects the individualized risk–benefit considerations that guide surgical decisions in older adults.

Limitations and Future Directions

The retrospective design precludes causal inference and outcome assessment. We cannot determine whether selection patterns optimized patient benefit. In addition, missing radiological data—bone density, fracture morphology, vertebral height loss—likely influence decisions; however, these data were unavailable.[33] Physician preferences, patient expectations, and socioeconomic factors substantially affect selection yet remain unmeasured.[27] Furthermore, single-timepoint VAS scores were used to capture pain intensity but not chronicity or duration. The single-system data from Southern Taiwan may not be generalizable to systems with different reimbursement, culture, or demographics.

Kyphoplasty, an alternative augmentation technique with favorable outcomes in selected patients,[10–12,23] was excluded because Taiwan's National Health Insurance rarely reimburses it; hence, no cases appeared in our dataset.[19,27] The results reflect local utilization patterns.

Future studies should incorporate comprehensive imaging,[34] validated patient-reported outcomes, decision-making documentation, and long-term follow-up. Multicenter trials stratifying by comorbidity and pain profiles could be used to identify optimal vertebroplasty candidates. Qualitative research examining patient and provider perspectives would illuminate non-clinical decision drivers. Developing and validating decision support tools integrating these factors represents a critical next step.

Conclusion

In this large real-world cohort of older adults with OVCFs, we identified multiple predictors of vertebroplasty selection, including old age, severe pain, specific comorbidities, and hospital type, highlighting clinical and institutional influences on decision-making. Importantly, these factors reflect patterns of treatment selection rather than validated indicators of treatment efficacy, and interpreting associations as causal inferences should be made cautiously. The paradoxical finding that select comorbidities increased the likelihood of vertebroplasty while higher overall comorbidity burden reduced it reveals complex clinical trade-offs that merit further investigation. Institutional variation in procedure rates may reflect differing interpretations of the evidence base and resource availability. Future prospective studies are needed to validate these predictors and assess their utility in guideline development and clinical decision-support tools.

Abbreviations

aOR, adjusted odds ratio; ATC, Anatomical Therapeutic Chemical; BMI, body mass index; CI, confidence interval; CCI, Charlson Comorbidity Index; ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification; ICD-10-CM, International Classification of Diseases, 10th Revision, Clinical Modification; KMUHRD, Kaohsiung Medical University Hospital Research Database; OVCF, osteoporotic vertebral compression fracture; PVP, percutaneous vertebroplasty; VAS, visual analog scale.

Data Sharing Statement

The data that support the findings of this study are available on request from the first author. The data are not publicly available due to privacy or ethical restrictions.

Ethics Statement

This study was approved by the Institutional Review Board of Kaohsiung Medical University Hospital (KMUH) (IRB No. KMUHIRB-E(I)-20230240). The requirement for informed consent was waived by the ethics committee because this was a retrospective study using de-identified medical records, which posed minimal risk to the participants. The study

was conducted in accordance with the Declaration of Helsinki and relevant local regulations to ensure the protection of patient data.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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