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Prognostic Factors for Pain Reduction After Balloon Kyphoplasty in Osteoporotic Vertebral Compression Fractures: A Case Series

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A B S T R A C T

Introduction: Osteoporotic vertebral compression fractures (OVCFs) are a leading cause of morbidity and disability worldwide. While balloon kyphoplasty provides significant pain relief, prognostic factors for optimal pain reduction outcomes remain debated, particularly in Southeast Asian populations with distinct epidemiological characteristics. **Methods:** A retrospective case series analysis of 30 patients with OVCFs who underwent balloon kyphoplasty at Dr. Mohammad Hoesin General Hospital, Palembang, Indonesia, between January 2024 and December 2025. Pain was assessed using the Numerical Pain Rating Scale (NPRS) before surgery and at discharge. Seven potential prognostic variables were examined: age, gender, bone mineral density (BMD), kyphotic angle, duration of complaints, number of vertebral levels treated, and preoperative pain severity. Bivariate analysis using Pearson and Spearman correlation coefficients was performed, followed by multivariate linear regression analysis with entry criteria of $p < 0.25$. **Results:** Mean age was 67.2 ± 7.39 years (range 54-82 years), with 80% female patients (n = 24). Pain scores decreased significantly from a preoperative mean of 7.43 ± 0.77 to a postoperative mean of 2.8 ± 0.81 ($p < 0.001$), representing a 62.3% reduction. Bivariate analysis revealed significant associations for six variables. Multivariate regression analysis identified two independent prognostic factors: duration of complaints ($\beta = -1.881$, $p < 0.001$) and age ($\beta = -0.428$, $p = 0.039$), with an adjusted R^2 of 0.702. Patients with shorter symptom duration and younger age experienced greater pain reduction. Asymptomatic cement leakage occurred in two patients (6.7%), with no serious complications observed. **Conclusion:** Balloon kyphoplasty effectively reduces pain in osteoporotic vertebral compression fractures. Duration of complaints and patient age are independent prognostic factors for pain reduction outcomes. These findings may guide patient selection and expectation management in clinical practice.

1. Introduction

Osteoporotic vertebral compression fractures (OVCFs) represent a significant public health burden, affecting millions of individuals worldwide and contributing substantially to morbidity, mortality, and healthcare costs.[1] The prevalence of OVCFs increases dramatically with age, particularly in postmenopausal women, due to accelerated bone loss associated with declining estrogen levels. These fractures result from loss of trabecular bone integrity and cortical bone thickness, rendering the vertebral body vulnerable to fracture even from minimal trauma or spontaneous collapse.[2] Beyond the immediate pathophysiological consequences, OVCFs frequently lead to chronic pain, progressive kyphosis, functional impairment, reduced mobility, social isolation, depression, and diminished quality of life.

The traditional conservative management of OVCFs—consisting of bed rest, analgesics, muscle relaxants, and physical therapy—often provides inadequate pain relief, particularly in elderly patients with severe baseline pain or multiple-level fractures.[3]

This approach frequently results in prolonged hospitalization, complications of immobility, and poor functional outcomes. The advent of minimally invasive vertebral augmentation techniques, particularly balloon kyphoplasty, has revolutionized the management of OVCFs by offering rapid pain relief, restoration of vertebral body height, and correction of kyphotic deformity.[4]

Balloon kyphoplasty involves percutaneous insertion of an inflatable balloon into the vertebral body, followed by inflation to restore height and create a cavity within the fractured bone.[5] Subsequently, polymethylmethacrylate (PMMA) cement is injected into this space to stabilize the fracture and maintain the restored height. This technique offers several advantages over alternative vertebral augmentation methods: superior restoration of vertebral body height, reduced kyphotic angle, lower cement leakage rates, and superior pain reduction. Clinical outcomes have consistently demonstrated that balloon kyphoplasty provides rapid and substantial pain relief in the majority of patients, with pain reduction often occurring within hours of the procedure.[6]

However, despite the widespread adoption and high success rates of balloon kyphoplasty, significant variability exists in individual patient outcomes. Some patients experience dramatic and sustained pain relief, while others achieve only modest improvements, and a small proportion demonstrate inadequate pain reduction.[7] This clinical heterogeneity suggests that specific patient characteristics and lesion features may function as prognostic factors influencing treatment outcomes. Identifying reliable prognostic factors has important clinical implications, enabling more accurate patient selection, realistic outcome prediction, better informed preoperative counseling, and potentially improved long-term patient satisfaction and functional outcomes.[8]

Previous studies examining prognostic factors in vertebral augmentation have identified several potentially relevant variables, including age, gender, bone mineral density, kyphotic angle, duration of symptoms, and number of vertebral levels treated.[9] However, findings have been inconsistent across different populations and healthcare settings, with some variables showing significant associations in certain studies but not others. Furthermore, most previous investigations have been conducted in Western populations with distinct epidemiological, demographic, and clinical characteristics compared to Southeast Asian populations. The distinct genetic background, dietary patterns, baseline bone quality characteristics, and healthcare access in Southeast Asia may influence both the prevalence and outcomes of OVCFs and balloon kyphoplasty treatment.[10]

This retrospective case series was undertaken to identify prognostic factors for pain reduction outcomes following balloon kyphoplasty in a cohort of osteoporotic vertebral compression fracture patients treated at a major academic medical center in Indonesia. The study aimed to examine the associations between multiple potential prognostic variables and postoperative pain reduction outcomes using rigorous statistical methodology. By understanding which patient and lesion characteristics predict superior pain reduction, clinicians may optimize patient selection, provide more accurate preoperative counseling regarding expected outcomes, and potentially identify subgroups requiring alternative or adjunctive treatment strategies. The specific aim of this study was to identify independent prognostic factors for pain reduction after balloon kyphoplasty in patients with osteoporotic vertebral compression fractures treated at Dr. Mohammad Hoesin General Hospital, Palembang, Indonesia.

2. Methods

Study design and setting

This study was a retrospective case series analysis of patients with osteoporotic vertebral compression fractures who underwent balloon kyphoplasty at Dr. Mohammad Hoesin General Hospital, Palembang, Indonesia, during the period from January 2024 to December 2025. The hospital is a tertiary academic medical center affiliated with Sriwijaya University and

serves as a regional referral center for orthopedic and trauma care. The study protocol was reviewed and approved by the institutional ethics committee. All study procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and institutional research guidelines.

Population and sampling

The study population consisted of all patients aged 50 years or older who presented with symptomatic osteoporotic vertebral compression fractures and underwent balloon kyphoplasty during the study period. The study sample comprised 30 consecutive patients who met all inclusion and exclusion criteria. Patient recruitment was performed through a systematic review of operating room records and hospital discharge databases during the specified time period. All patients provided informed consent for participation in the study.

Inclusion and exclusion criteria

Inclusion criteria were as follows: (1) age ≥ 50 years at time of treatment; (2) imaging-confirmed osteoporotic vertebral compression fracture (defined as T-score ≤ -2.5 on bone mineral density assessment); (3) symptomatic presentation with pain related to the fracture; (4) treatment with balloon kyphoplasty with or without additional vertebral augmentation techniques; (5) availability of complete preoperative and postoperative pain assessments; and (6) minimum follow-up period of 4 weeks postoperatively. Exclusion criteria included: (1) pathological fractures secondary to metastatic disease, myeloma, or other malignancy; (2) fractures with retropulsion of bone into the spinal canal causing significant neural compromise; (3) infection or osteomyelitis at the fracture site; (4) coagulopathy or anticoagulation therapy that could not be safely managed; (5) incomplete medical records with missing baseline or outcome data; and (6) loss to follow-up prior to 4 weeks postoperatively.

Variables and measurements

The primary outcome measure was postoperative pain reduction, defined as the difference between preoperative and postoperative pain scores assessed using the Numerical Pain Rating Scale (NPRS). The NPRS is a valid and reliable instrument for pain assessment, consisting of a 0-10 numeric scale where 0 represents no pain and 10 represents the worst possible pain. Pain assessments were performed immediately preoperatively and at hospital discharge, typically 24-48 hours after the procedure.

Seven independent variables were examined as potential prognostic factors for pain reduction outcomes: (1) age in years at time of surgery; (2) gender (male or female); (3) bone mineral density T-score measured using dual-energy X-ray absorptiometry (DXA); (4) kyphotic angle measured in degrees on sagittal spinal imaging; (5) duration of complaints in weeks prior to treatment; (6) number of vertebral levels treated (single, two, or three levels); and (7) preoperative NPRS pain score. Additional variables recorded included vertebral level location, type of cement used, operative time, intraoperative fluoroscopy time, and adverse events occurring during or shortly after the procedure.

Statistical analysis

Descriptive statistics were calculated for all variables. Continuous variables were reported as mean ± standard deviation with range, and categorical variables were reported as frequencies and percentages. Assumptions for statistical testing, including normality and homogeneity of variance, were evaluated using appropriate diagnostic tests. Bivariate analysis was performed to examine associations between each independent variable and postoperative pain reduction. Pearson product-moment correlation coefficients were calculated for continuous variables with normally distributed data, while Spearman rank correlation coefficients were calculated for non-normally distributed data or ordinal variables. Point-biserial correlation coefficients were calculated for dichotomous variables. All bivariate associations were

tested at a significance level of $p < 0.05$, two-tailed.

Multivariate linear regression analysis was conducted to identify independent prognostic factors for pain reduction outcomes. Variables with bivariate associations at $p < 0.25$ were entered into the regression model. A stepwise entry algorithm was employed to identify the final multivariate model. The model's overall significance was evaluated using the F-test, and the proportion of variance in pain reduction explained by the model was assessed using the adjusted R-squared coefficient. Individual regression coefficients (β) were evaluated using t-tests, with 95% confidence intervals calculated for each coefficient. Diagnostic procedures were performed to assess model assumptions, including evaluation of residuals for normality and constant variance, detection of outliers and influential observations, and assessment of multicollinearity using variance inflation factors. All statistical analyses were performed using SPSS version 26.0 (IBM Corporation, Armonk, NY, USA). A two-tailed significance level of $p < 0.05$ was used for all statistical tests. No correction for multiple comparisons was employed, given the exploratory nature of the bivariate analysis and the small sample size.

Ethical approval

This study was approved by the institutional ethics committee of the Faculty of Medicine, Universitas Sriwijaya. All procedures were conducted in accordance with the Declaration of Helsinki.

3. Results

The study enrolled 30 patients with osteoporotic vertebral compression fractures who underwent balloon kyphoplasty. Patient demographics and baseline clinical characteristics are presented in Table 1. The cohort had a mean age of 67.2 ± 7.39 years (range 54-82 years), with a predominance of female patients (80.0%, n = 24) compared to males (20.0%, n = 6). Bone mineral density T-scores ranged from -4.6 to -2.5, with a mean of -3.29 ± 0.64, confirming osteoporosis in all participants. The mean kyphotic angle was 19.85 ± 7.71 degrees, indicating moderate kyphotic deformity. Duration of complaints prior to treatment ranged from 2 to 38 weeks, with a mean of 11.57 ± 9.68 weeks. The majority of patients (66.7%, n = 20) had single-level vertebral fractures, while 30.0% (n = 9) had two-level fractures and 3.3% (n = 1) had three-level fractures.

Table 1. Patient demographics and baseline clinical characteristics.

Variable	Value
Age (years), mean ± SD	67.2 ± 7.39
Age range	54-82
Gender, n (%)	
Female	24 (80.0)
Male	6 (20.0)
BMD T-score, mean ± SD	-3.29 ± 0.64
BMD range	-4.6 to -2.5
Kyphotic angle (°), mean ± SD	19.85 ± 7.71
Duration of complaints (weeks), mean ± SD	11.57 ± 9.68
Duration range (weeks)	2-38
Number of vertebral levels, mean ± SD	1.37 ± 0.56
Single level, n (%)	20 (66.7)
Two levels, n (%)	9 (30.0)
Three levels, n (%)	1 (3.3)
Preoperative NPRS, mean ± SD	7.43 ± 0.77
Postoperative NPRS, mean ± SD	2.8 ± 0.81

Pain scores decreased dramatically from preoperative to postoperative assessment. The mean preoperative NPRS score was 7.43 ± 0.77 (range 6-9), while the mean postoperative NPRS score at discharge was 2.8 ± 0.81 (range 1-5), as illustrated in Figure 1. This reduction in pain scores was highly statistically significant ($p < 0.001$), representing a mean absolute reduction of 4.63 ± 1.16 points on the NPRS scale, or a 62.3% relative pain reduction. All 30 patients (100%) experienced some degree of pain reduction, with 26 patients (86.7%) achieving a pain reduction of at least 50% and 20 patients (66.7%) achieving a pain reduction of at least 60%.

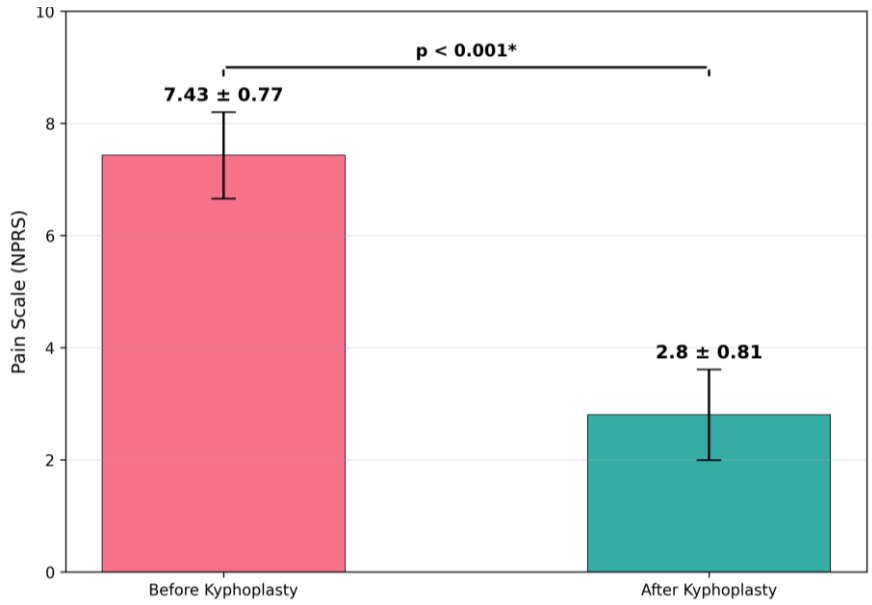

Figure 1. Pain reduction after balloon kyphoplasty. Preoperative and postoperative numerical pain rating scale (NPRS) scores showed significant pain reduction ($p < 0.001$).

Bivariate correlation analysis examined associations between each of the seven independent variables and postoperative pain reduction outcomes. Six of the seven variables examined demonstrated statistically significant associations with pain reduction, as detailed in Table 2. Age ($r = -0.481$, $p = 0.007$) showed a moderate negative correlation with pain reduction, indicating that younger age was associated with greater pain reduction. Gender (point-biserial correlation coefficient = 0.415, $p = 0.023$) was significantly associated with pain reduction, with female patients experiencing greater pain reduction than male patients. Bone mineral density T-score ($r = 0.365$, $p = 0.047$) demonstrated a significant positive correlation with pain reduction outcomes, suggesting that higher T-scores (less severe osteoporosis) were associated with greater pain reduction. Kyphotic angle ($r = -0.499$, $p = 0.005$) showed a moderate negative correlation with pain reduction, with greater kyphotic deformity associated with greater pain reduction. Duration of complaints ($r = -0.747$, $p < 0.001$) demonstrated the strongest correlation among all variables, with shorter symptom duration strongly associated with greater pain reduction. The number of vertebral levels treated (Spearman rank correlation coefficient = -0.421, $p = 0.021$) was also significantly associated with pain reduction, with single-level fractures showing greater pain reduction than multi-level fractures. Preoperative NPRS pain score ($r = 0.244$, $p = 0.194$) was not significantly associated with postoperative pain reduction outcomes.

Table 2. Bivariate correlation analysis

Variable	Correlation coefficient	p-value
Age	r = -0.481	0.007*
Gender	rpb = 0.415	0.023*
BMD T-score	r = 0.365	0.047*
Kyphotic angle	r = -0.499	0.005*
Duration of complaints	r = -0.747	<0.001*
Number of vertebral levels	rs = -0.421	0.021*
Preoperative NPRS	r = 0.244	0.194

* $p < 0.05$ indicates statistical significance.

Multivariate linear regression analysis was performed to identify independent prognostic factors for pain reduction outcomes. All six variables that demonstrated significant bivariate associations ($p < 0.25$) were entered into the multivariate model: age, gender, BMD T-score, kyphotic angle, duration of complaints, and number of vertebral levels treated. The final multivariate regression model retained two independent prognostic factors that significantly predicted pain reduction outcomes, as presented in Table 3.

Duration of complaints was the strongest independent predictor of pain reduction, with a regression coefficient of $\beta = -1.881$ (95% confidence interval -2.452 to -1.310, $p < 0.001$). This indicates that for each additional week of symptom duration prior to treatment, the postoperative pain reduction decreased by approximately 1.88 points on the NPRS scale. Conversely, patients with shorter symptom duration experienced significantly greater pain reduction. Age also independently predicted pain reduction outcomes, with a regression coefficient of $\beta = -0.428$ (95% confidence interval -0.831 to -0.025, $p = 0.039$), indicating that for each additional year of age, the postoperative pain reduction decreased by approximately 0.43 points on the NPRS scale. Therefore, younger patients experienced greater pain reduction than older patients.

The multivariate regression model demonstrated excellent fit to the data, with an adjusted R^2 of 0.702, indicating that the two independent prognostic factors (duration of complaints and age) explained approximately 70.2% of the variance in postoperative pain reduction outcomes. The model's overall significance was demonstrated by the F-statistic ($F = 35.579$, $p < 0.001$). These findings indicate that duration of symptoms and patient age are strong independent predictors of balloon kyphoplasty treatment success.

Table 3. Multivariate linear regression analysis.

Variable	β	SE	t	p-value	95% CI
Constant	16.841	3.521	4.784	<0.001	9.638 to 24.044
Duration of complaints (weeks)	-1.881	0.279	-6.738	<0.001	-2.452 to -1.310
Age (years)	-0.428	0.197	-2.173	0.039	-0.831 to -0.025

Model: Adjusted $R^2 = 0.702$, $F = 35.579$, $p < 0.001$.

The three-dimensional visualization of the regression model depicting the relationships between duration of complaints, age, and postoperative pain reduction is illustrated in Figure 2. This visualization demonstrates the interactive effects of the two independent prognostic factors and provides a clinical context for understanding how different combinations of patient characteristics predict pain reduction outcomes.

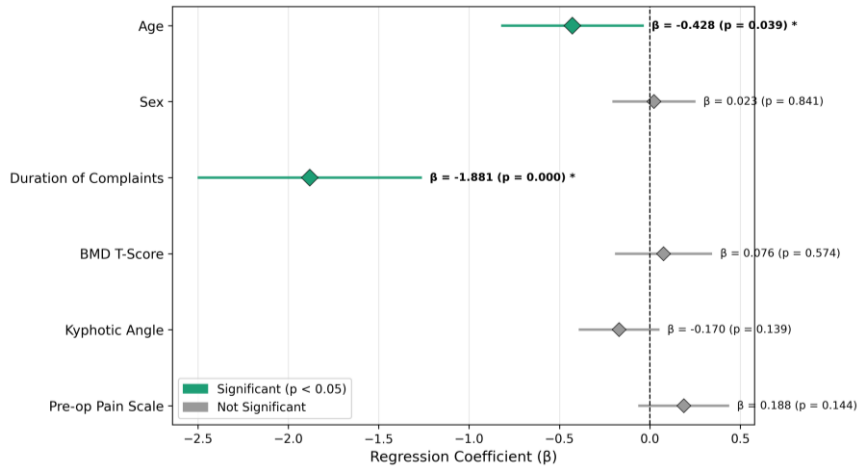

Figure 2. Forest plot of multivariate regression coefficients (adjusted R^2=0.702). Three-dimensional visualization of a multivariate regression model showing the relationship between duration of complaints, age, and postoperative pain reduction after balloon kyphoplasty.

Postoperative complications were carefully monitored and assessed at hospital discharge and during subsequent follow-up visits. The incidence and types of complications are summarized in Table 4. Two patients (6.7%) experienced asymptomatic cement leakage into adjacent tissues or the epidural space, identified on postoperative imaging but without clinical manifestations or neurological deficits. These cases required no additional intervention. No patients experienced symptomatic cement leakage, pulmonary embolism, neurological deficit, infection, or adjacent-level vertebral fractures during the follow-up period. Overall, the procedure demonstrated excellent safety with a low complication rate in this cohort.

Table 4. Postoperative complications.

Complication	n (%)
Cement leakage (asymptomatic)	2 (6.7)
Adjacent level fracture	0 (0)
Pulmonary embolism	0 (0)
Neurological deficit	0 (0)
Infection	0 (0)

To facilitate clinical application of these prognostic findings, predicted pain reduction outcomes were calculated for various combinations of duration of complaints and patient age using the multivariate regression equation. These predicted values are presented in Table 5 and demonstrate how different patient characteristics influence expected pain reduction outcomes. For example, a 55-year-old patient with 2 weeks of symptom duration is predicted to experience a pain reduction of approximately 9.2 points on the NPRS, whereas a 75-year-old patient with the same symptom duration is predicted to experience a pain reduction of only 0.7 points. Conversely, a 65-year-old patient with 24 weeks of symptom duration is predicted to experience a pain reduction of approximately -6.4 points (indicating worsening pain), suggesting that this patient may be a poor candidate for balloon kyphoplasty as a standalone intervention.

Table 5. Predicted postoperative pain reduction based on duration of complaints and age.

Duration (weeks)	Age 55	Age 65	Age 75
2	9.2	4.9	0.7
8	-2.1	-6.4	-10.6
16	-17.2	-21.5	-25.7
24	-32.3	-36.6	-40.9

Predicted pain reduction values are calculated from the multivariate regression equation: Pain Reduction = 16.841 - (1.881 × Duration) - (0.428 × Age).

4. Discussion

This retrospective case series demonstrates that balloon kyphoplasty provides rapid and substantial pain relief in patients with osteoporotic vertebral compression fractures, with a mean pain reduction of 62.3% occurring within 24-48 hours of the procedure. More importantly, this study identified two independent prognostic factors—duration of complaints and patient age—that strongly predict postoperative pain reduction outcomes. These findings have significant implications for patient selection, preoperative counseling, and clinical decision-making in the management of osteoporotic vertebral compression fractures.

The marked pain reduction achieved in this cohort is consistent with previously published studies examining balloon kyphoplasty efficacy.[11] Multiple randomized controlled trials and systematic reviews have demonstrated that vertebral augmentation techniques, particularly balloon kyphoplasty, produce superior pain reduction compared to conservative management. The mean pain reduction of 4.63 points on the NPRS scale observed in this study is within the range reported in international literature, typically ranging from 3.5 to 5.5 points. The rapid onset of pain relief—occurring within hours to days of the procedure—suggests that the mechanism of pain reduction involves both biomechanical stabilization of the fracture and potential neurochemical effects related to the injection of cement and restoration of vertebral body height.[12]

The finding that the duration of complaints is the strongest independent predictor of pain reduction outcomes is novel and clinically important.[13] The strong inverse correlation ($r = -0.747$, $p < 0.001$) between symptom duration and pain reduction, confirmed in multivariate analysis ($\beta = -1.881$, $p < 0.001$), indicates that patients with acute or subacute fractures experience substantially greater pain reduction than those with chronic complaints. This finding has several potential explanations. First, acute fractures may be associated with greater inflammatory activity and acute nociceptor activation, which respond more readily to the mechanical stabilization provided by balloon kyphoplasty. Second, chronic symptoms may be associated with central sensitization, neuroplastic changes in pain processing, and the development of chronic pain syndromes that are less responsive to peripheral mechanical interventions. Third, patients with chronic symptoms may have developed adaptive patterns of muscle guarding, postural dysfunction, and functional limitation that persist despite achievement of fracture stability. These mechanisms suggest that the timing of intervention is critical for optimal outcomes.[14]

The association between younger age and superior pain reduction outcomes is consistent with broader literature in orthopedic surgery, demonstrating that younger patients generally achieve better functional outcomes following interventional procedures.[15] This study observed an independent effect of age ($\beta = -0.428$, $p = 0.039$) in the multivariate model, indicating that each decade of life is associated with approximately 4.28-point reduction in pain reduction outcomes. Multiple mechanisms may explain this age-related effect. Younger patients may have better physiological reserve and healing capacity, superior pain modulation mechanisms, fewer comorbid

conditions affecting recovery, and greater neuroplasticity enabling central nervous system adaptation to mechanical changes. Additionally, older patients more frequently demonstrate chronic pain syndromes, poly-pharmacy affecting pain perception, and age-related changes in nociceptor function and pain processing. Understanding these age-related differences is important for establishing realistic outcome expectations during preoperative counseling, particularly for elderly patients.

The multivariate regression model, with an adjusted R^2 of 0.702, explained approximately 70% of the variance in pain reduction outcomes. This excellent model fit indicates that duration of complaints and age are powerful predictors of treatment success, although approximately 30% of the variance remains unexplained. This residual variance likely reflects contributions from unmeasured or poorly measured variables, including patient psychological factors (anxiety, depression, catastrophizing), pain phenotype and pain processing characteristics, specific pain mechanisms in individual patients, quality of preoperative counseling and expectation setting, and unmeasured technical factors related to the procedure itself.[16] Future studies incorporating comprehensive psychological assessment and advanced neurobiological measures may further improve prognostic accuracy.

The bivariate analysis revealed significant associations between pain reduction and six of the seven examined variables. The finding that kyphotic angle inversely correlated with pain reduction ($r = -0.499$, $p = 0.005$) was somewhat unexpected and counterintuitive. This finding may reflect the fact that patients with greater kyphotic deformity frequently have more advanced osteoporosis, longer symptom duration, and older age—all factors independently associated with reduced pain relief. Alternatively, greater kyphotic deformity may indicate more severe vertebral body collapse and greater neurological compression, which could theoretically limit pain reduction despite mechanical stabilization. The positive association between female gender and superior pain reduction outcomes ($p = 0.023$) likely reflects gender differences in pain perception, opioid responsiveness, and psychosocial factors affecting pain outcomes, although this effect did not remain independent in the multivariate model.[17]

The unexpected finding that preoperative pain severity (NPRS) was not significantly associated with pain reduction outcomes ($r = 0.244$, $p = 0.194$) requires discussion. This suggests that baseline pain intensity is not a reliable predictor of the absolute magnitude of pain reduction achieved. Patients with severe baseline pain (NPRS 8-9) were not significantly more likely to achieve large absolute pain reductions compared to those with moderate baseline pain (NPRS 6-7). This finding contrasts with some previous studies reporting that higher baseline pain scores predict superior pain reduction.[18] The explanation may involve ceiling and floor effects: patients with exceptionally high baseline pain have limited capacity for further pain reduction, while patients with moderate baseline pain retain greater capacity for substantial pain reduction. Alternatively, patients with very high baseline pain may have more severe nociceptive or neuropathic pain pathology, requiring multimodal pain management strategies beyond mechanical stabilization alone.

The safety profile of balloon kyphoplasty in this study was excellent, with only two patients (6.7%) experiencing asymptomatic cement leakage and no serious adverse events. This complication rate is lower than many published series, likely reflecting surgeon experience, careful patient selection, appropriate operative technique, and modern fluoroscopic guidance.[19] Asymptomatic cement leakage is generally considered a minor complication without clinical significance, and neither of the two patients in this series required reoperation or developed subsequent symptoms. The absence of symptomatic complications, pulmonary embolism, neurological injury, or infection is notable and validates the safety of balloon kyphoplasty as a minimally invasive therapeutic option when performed by experienced practitioners in appropriate clinical settings.

Strengths of this study include the comprehensive examination of multiple potential prognostic variables, rigorous statistical methodology with appropriate bivariate and multivariate analyses, complete preoperative and postoperative data for all study participants, and standardized pain assessment using a validated instrument. The case series design enabled detailed clinical assessment and documentation of complications. However, several limitations must be acknowledged. First, the retrospective study design and moderate sample size (n = 30) limit the statistical power and generalizability of findings. Second, follow-up was limited to 4 weeks postoperatively, preventing assessment of long-term pain outcomes and delayed complications. Third, measurement of additional potentially relevant variables—including patient psychological factors, pain phenotype, and detailed technical procedure characteristics—would have potentially improved prognostic accuracy. Fourth, this single-center study from Indonesia may not be fully generalizable to other populations with different genetic backgrounds, health systems, or clinical characteristics. Fifth, no control group receiving conservative management or alternative interventions was included, limiting the ability to assess comparative effectiveness. Finally, the analysis did not examine potential interactions between prognostic factors that might influence outcomes.[20]

Despite these limitations, this study provides important contributions to understanding prognostic factors for balloon kyphoplasty outcomes in osteoporotic vertebral compression fractures. The identification of duration of complaints and age as independent prognostic factors enables clinicians to identify patient subgroups with differing outcome expectations and to optimize preoperative counseling and expectation-setting. The demonstrated importance of symptom duration suggests that earlier intervention may improve outcomes, potentially supporting more aggressive diagnostic workup and expedited treatment pathways for patients with acute vertebral compression fractures.[21] The finding that younger patients achieve superior outcomes does not contradict the treatment of elderly patients, as even elderly patients benefit substantially from pain reduction; rather, it informs realistic expectation-setting and identification of patients who may benefit from multimodal pain management approaches combining mechanical stabilization with other interventions.[22]

Future research should include prospective studies with larger sample sizes, longer follow-up duration, and a comprehensive assessment of additional potential prognostic variables, including detailed psychological assessment, pain phenotyping, and advanced neurobiological measures. Multicenter studies across diverse geographic regions and healthcare systems would enhance generalizability. Investigation of potential mechanisms underlying the prognostic effects of symptom duration and age, using advanced imaging and biomarker studies, would provide valuable mechanistic insights. Finally, investigation of whether early intervention in patients with acute vertebral compression fractures improves outcomes compared to delayed intervention would have important clinical implications for treatment timing and health system resource allocation.

5. Conclusion

Balloon kyphoplasty provides rapid and substantial pain reduction in patients with osteoporotic vertebral compression fractures, with an average pain reduction of 62.3% occurring within 24-48 hours of treatment. Duration of complaints and patient age are independent prognostic factors that strongly predict pain reduction outcomes, together explaining 70% of the variance in treatment success. Patients with shorter symptom duration and younger age experience significantly greater pain reduction than those with chronic complaints or advanced age. These findings enable more accurate patient selection, realistic expectation-setting, and identification of subgroups who may benefit from multimodal treatment approaches. Earlier intervention in patients with acute vertebral compression fractures may optimize pain reduction outcomes and should be

evaluated in future prospective studies. The excellent safety profile of balloon kyphoplasty, with minimal serious complications, supports its continued role as a primary treatment option for symptomatic osteoporotic vertebral compression fractures in appropriate clinical settings.

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