ISSN: 2149-2018

Applied Medical Research, 2025
VOL 12, NO. 10, PAGE 1 – 5
DOI: doi.org/10.47363/AMR/2025(12)273

RESEARCH ARTICLE

Open Access

Insights on Kyphoplasty: A Retrospective Analysis of Intraoperative Variables and Patient Demographics

Wickman E, Hutchinson SR and Wickman AM*

Alta Orthopaedics, 510 Castillo Street, Suite 203, Santa Barbara, CA 93101, USA

ABSTRACT

Background Context: Vertebral compression fractures are the most common fragility fracture in the world and, with an increasing elderly population, are predicted to comprise a significant portion of spinal health care costs. Although kyphoplasty is accepted as a common treatment option, further details of its procedural aspects are less well established.

Purpose: This study aimed to highlight the relationships between age, sex, and spinal levels treated by kyphoplasty and balloon pressure, volume, and cement volume.

Study Design: Single Surgeon Observation Study

Patient Sample: 77 patients with VCF undergoing kyphoplasty with the author (SRH) between April 2023 to September 2024.

Methods: Procedural kyphoplasty measurements of balloon pressure, balloon volume, and cement volume were recorded. The inclusion criteria included patients with known osteoporotic fracture and failure of non-operative management. Only patients with acute or subacute osteoporotic compression fractures were included. Exclusion criteria included previous surgery at the spinal level and VCF due to non-osteoporotic etiology (i.e. trauma or neoplasm).

Results: A total of 141 levels were included in this study. There were 77 patients; 61% female, 39% male. 54 thoracic levels were treated with a mean age of 77.0 (females) and 74.7 (males). 87 lumbar levels were treated, with a mean age of 79.3 (females) and 77.9 (males). There was a statistically significant relationship between age (by decade) and region (T vs. L spine) (p=.013). Of the 77 patients, 19% underwent surgery on multiple dates (n=15). Pressure analysis revealed that the mean inflation pressure was 152.5 PSI for thoracic spine levels and 147.5 PSI for lumbar spine levels. This was not statistically significant but there was a significant correlation between age by decade and the mean pressure (p=0.0014). When spinal levels were grouped anatomically (T6-9, T10-L1, L2-5), there was a statistically significant relationship between spinal grouping and pressure (p=0.044). The mean balloon volume was 2.42 cc for the thoracic spine levels and 2.89 cc for the lumbar spine levels. Balloon volume and age by decade were significant, with a (p=0.0137). In addition, statistically significant relationships were identified between balloon volume and level (p=0.014) and between balloon volume and age by decade (p=0.003). However, no statistically significant correlation was found between balloon volume and sex. The mean cement volume was 2.27 cc for the thoracic spine levels and 2.92 cc for the lumbar spine levels. Cement volume demonstrated a significant relationship with spinal level (p<.001). Cement volume analysis revealed a statistically significant relationship between mean cement volume and sex (p = 0.0255, two-way ANOVA). Males required higher cement volumes than females (p<.0001). Cement volume significantly correlated with age by decade (p=0.034). Advanced age requires a higher cement volume.

Conclusion: Age, sex, and spinal level can significantly influence procedural components during kyphoplasty for osteoporotic VCF. Both thoracic and lumbar fractures have different procedural requirements, with greater demands on the balloon and cement quantities at the lumbar levels. Variations in sex and age emphasize the importance of personalized surgical planning in the optimization of patient outcomes.

ARTICLE HISTORY

Received October 06, 2025
Accepted October 09, 2025
Published October 20, 2025

KEYWORDS

Vertebral Compression Fractures, Kyphoplasty, Osteoporosis, Balloon Volume, Balloon Pressure, Cement Volume, Age, Sex, Spinal Level, Thoracic Spine, Lumbar Spine, Osteoporosis

Contact Wickman AM, Alta Orthopaedics, 510 Castillo Street, Suite 203, Santa Barbara, CA 93101, USA.

© 2025 The Authors. This is an open access article under the terms of the Creative Commons Attribution NonCommercial ShareAlike 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/).

Introduction

Osteoporotic vertebral compression fractures (OVCFs) are among the most common complications of osteoporosis, and the most common fragility fractures reported [1]. With a rapidly growing elderly population worldwide, OVCFs have emerged as an important public health concern. It has been shown that up to 50% of patients aged ≥ 80 years have a vertebral compression fracture when worked up for a separate medical condition [2].

These fractures often lead to severe pain and progressive sagittal imbalance and have a mortality rate of up to 72% in 5 years [3]. OVCFs also lead to a worse health-related quality of life [4]. Kyphoplasty is a minimally invasive vertebral augmentation procedure that has been widely adopted for the treatment of acute and subacute OVCFs. This procedure includes inserting a cannulated trocar into the fractured vertebral body, inflating a balloon to reduce and correct the fracture, and injecting cement to restore and maintain vertebral height [5]. Kyphoplasty has been shown to reduce pain and allow a faster return to mobilization [6]. The efficacy and safety of kyphoplasty have been extensively studied, but there is little literature on the technical aspects of the procedure. This single-surgeon prospective study aimed to evaluate changes in balloon pressure and volume, along with cement volume, with regard to age, sex, and spinal level. Given the potential for these factors to influence patient outcomes, including adjacent-level fractures, a comprehensive analysis of the demographic and procedural variables is warranted.

Methods

This was a single-surgeon observational study of kyphoplasty performed in OVCFs.

Data was collected and de-identified from patients who underwent a kyphoplasty with the surgeon (SRH) between April 2023 and September 2024. The surgical procedures were performed by the author using the standard kyphoplasty technique. Data was collected on balloon pressure, balloon volume, and cement volume. All surgical dates were collected, including a single date of surgery (DOS) and multiple DOS. All spinal levels were treated, and any adjacent-level involvement was collected. Spinal levels were evaluated based on both thoracic and lumbar locations and anatomically stratified as thoracic (T6-9, T10-L1) and lumbar (L2-L5) to facilitate subgroup analysis. Data on key demographic characteristics, including age and sex, were collected.

The inclusion criteria were patients with a known osteoporotic fracture and failure of non-operative management. Osteoporosis status was confirmed by DEXA or clinical history (including but not limited to fragility fractures). Vertebral compression fracture diagnosis was based on radiographic imaging studies (magnetic resonance imaging [MRI], radiographs, or bone scans). Only patients with acute or subacute osteoporotic vertebral compression fractures with active inflammatory markers based on imaging and clinical evaluations were included.

Exclusion criteria included pathological fractures due to metastatic cancer, traumatic fractures of non-osteoporotic bones, or a history of previous surgery at the same vertebral level. This study had only one excluded patient.

Data Collection

Data were retrospectively extracted from the medical records of all patients meeting the inclusion criteria. Demographic variables included patient age, categorized into decades and broader groups (under 65, 65-80, over 80 years), and sex. Procedural data included separate-side balloon volume, balloon pressure, and cement volume for each vertebral level treated. Fractures were analyzed individually by level and region, and grouped into thoracic and lumbar classifications for regional comparisons.

Surgical cases were recorded as single versus multiple DOS, with data on adjacent-level involvement and time intervals between surgeries for patients undergoing multiple procedures. Patient outcomes were further stratified by spinal level and region, age, sex, and surgical timing to evaluate the differences in procedural parameters. For a more detailed analysis, regional subgrouping included T6-T9, T10-L1, and L2-L5.

The data collected was organized for statistical analysis, highlighting the correlations between demographic factors, such as age and sex, and procedural metrics, such as balloon volume, cement volume, and pressure. Subgroup analyses were conducted to determine whether these variables influenced treatment outcomes, adjacent-level involvement, or the need for multiple surgeries.

Statistical Analysis

All analyses were performed using standard analytical tools to examine the associations between demographic, procedural, and outcome variables. Descriptive statistics included means and standard deviations for continuous variables such as age, balloon volume, balloon pressure and cement volume. Frequencies and percentages were used to summarize categorical variables, including sex, age, and the spinal region. The spinal region was initially categorized as the thoracic (T6-T12) and lumbar spine (L1-L5). Further evaluation of spinal regions was performed using anatomically similar categories. They were categorized into the following groups: T6-9, T10-L1, and L2-5.

The statistical tests used were inferential and aimed at ascertaining significant relationships between variables. Comparisons of continuous variables across groups, including pressure, balloon volume, and cement volume by spinal level and region, were analyzed by ANOVA. Chi-square tests were performed to assess categorical relationships such as age and sex. Two-way ANOVA models were applied to determine the interaction of demographic factors with procedural variables, such as the impact of age and sex on cement volume.

Statistical significance was set at $p<0.05$. Specific analyses included comparisons of thoracic versus lumbar regions, single versus multiple surgical dates, and age and sex-related variations in procedural metrics. Subgroup analyses for regional differences were performed using both raw and grouped levels categorized as T6-T9, T10-L2, and L3-L5.

Results

A total of 142 levels were identified. One level was excluded because of a pathological compression fracture from the neoplasm, leaving 141 levels included in this study. There were 77 patients. Females comprised 61% (47 patients) and males comprised 39% (30 patients). The mean age of female patients at the date of surgery (DOS) was 78.5 years, and for males, it was 76.6 years.

Fifty-four levels were treated for the thoracic spine. The mean age of the thoracic VCFs was 76.0 years. The mean age for VCF in females was 77.0 years and 74.7 years for males. Of the total thoracic VCFs, females were 57% (31 levels), 43% (23 levels) were male.

Eighty-seven levels were treated for the lumbar spine. The mean age of the lumbar VCFs was 78.8 years. The mean age for VCF in females was 79.3 years and 77.9 years for males.

Females represented 61% (53 levels) and males accounted for 39% (34 levels) of lumbar VCFs. There was a statistically significant relationship between age (by decade) and region (T vs. L spine), with a p-value of 0.013 (chi-square test) (Figure 1).

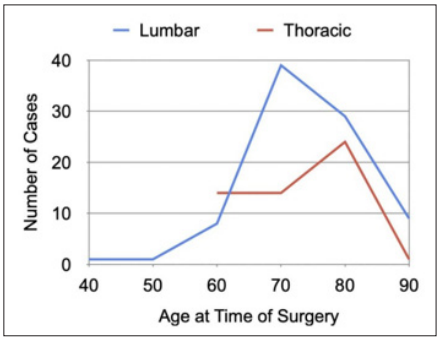

Figure 1: Age (by decade) in Relation to Location (Thoracic and Lumbar)

Of 77 patients, 15 underwent surgery on multiple dates, representing 19% of the cohort. The average age of these patients was determined from their age at each DOS. These patients had a slightly higher mean age (77.8 years) compared to those treated at a single DOS (77.7 years). Among these patients with multiple DOS, 67% were female, and 33% were male.

Pressure analysis revealed that the mean inflation pressure was 152.5 PSI for thoracic spine levels and 147.5 PSI for lumbar spine levels. While no statistically significant relationship was found between sex and mean pressure there was a significant correlation between age by decade and mean pressure (p=0.001397, ANOVA) (Figure 2).

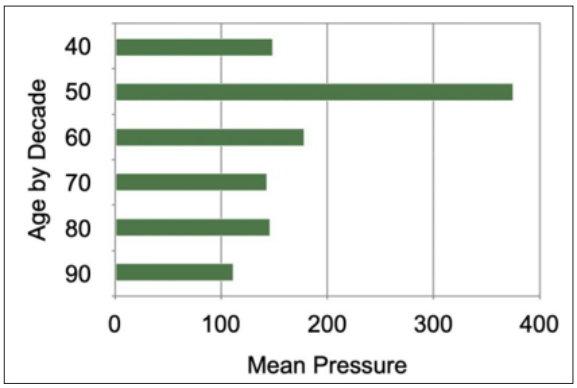

Figure 2: Age (by decade) in Relation to Mean Pressure

Although there was no significant relationship between level and pressure, when spinal levels were grouped anatomically, a statistically significant relationship between spinal grouping (T6-9, T10-L1, L2-5) and pressure was observed (p=0.043992, ANOVA). (Figure 3)

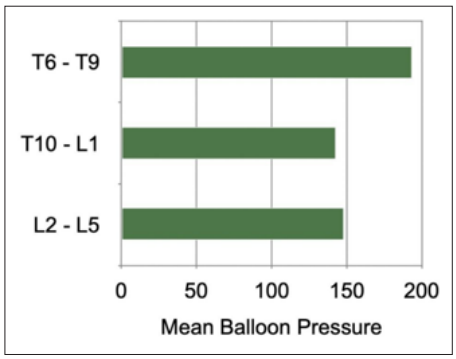

Figure 3: Spine Grouping in Relation to Balloon Pressure

The mean balloon volume was 2.42 cc for the thoracic spine levels and 2.89 cc for the lumbar spine levels. A statistically significant difference was observed between balloon volume and age by decade, with a p-value of 0.0137 (ANOVA). A statistically significant relationship was identified between balloon volume and level (p=0.013691, ANOVA) and between balloon volume and age by decade (p=0.003164, ANOVA). However, no statistically significant correlation was found between balloon volume and sex.

The mean cement volume was 2.27 cc for the thoracic spine levels and 2.92 cc for the lumbar spine levels. Cement volume demonstrated significant relationships with spinal level (p=0.000001, ANOVA).

When further evaluated by anatomic grouping, the correlation is much more pronounced with a p-value of 2.602976*10-8 (ANOVA). Cement volume analysis revealed a statistically significant relationship between mean cement volume and sex (p = 0.0255, two-way ANOVA). Males required higher cement volumes than females (p = 0.000006 for spine level) (Figure 4).

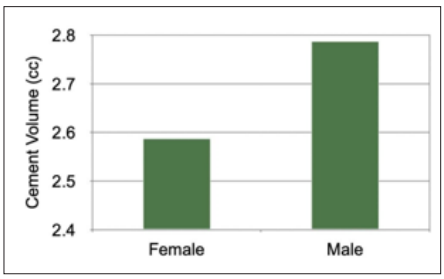

Figure 4: Gender in Relation to Cement Volume (CC)

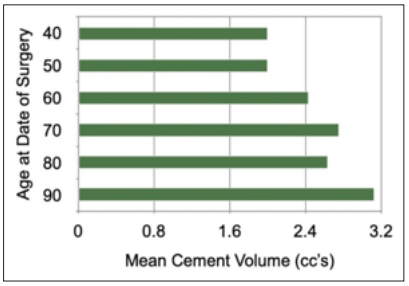

Figure 5: Cement Volume in Relation to age (by decade)

Cement volume was significantly correlated with age by decade (p=0.0339, ANOVA) (Figure 5). Advanced age requires a higher cement volume.

Discussion

The results of this study provide insights into the relationships among patient demographics, spinal regions, and procedural variables in kyphoplasty. Several patterns have emerged that highlight the interplay between anatomical, physiological, and procedural factors.

In this study, there were more lumbar fractures than thoracic spine fractures, which is consistent with existing literature [7]. Sopon et al. suggest that lumbar spine fractures are due to biomechanical differences, with a more mobile lumbar spine versus a more rigid thoracic spine constrained by the ribs and sternum [8]. The statistically significant difference in mean ages between the thoracic and lumbar regions (p=0.0135) underscores the potential influence of age-related bone quality and fracture susceptibility across spinal regions. The highest incidence of thoracic fractures occurred at an older age than the highest incidence of lumbar fractures (Figure 1). However, it is unclear why this occurred. This could be due to increased physical activity at a younger age, resulting in fractures of the mobile lumbar spine.

The stratification of spinal levels into subgroups (T6-9, T10-L1, L2-5) revealed a more statistically significant relationship between spinal grouping and procedural outcomes than the index spinal levels (T vs L spine). This is likely due to the anatomical characteristics of the thoracolumbar junction, where L1 exhibits biomechanical properties closer to the lower thoracic spine than to the lumbar spine.

Balloon and cement volumes showed significant relationships with spinal region, age, and in the case of cement, sex. This finding underscores the influence of age on the amount of balloon inflation required during kyphoplasty. The mean cement volume was higher in males, which may reflect differences in fracture morphology or bone density, but likely due to greater skeletal size [9]. Similarly, the increase in cement volume with advancing age (p=0.0339) may indicate larger fracture voids or diminished bone quality in older patients (Figure 5).

This difference may reflect sex-specific variations in fracture morphology or bone quality, further emphasizing the need for personal approaches to kyphoplasty. These observations support the hypothesis that both increasing fracture size and worsening bone quality contribute to the procedural requirements [10]. Further investigation with direct measures of bone mineral density and actual vertebral body size (e.g. CT scans) could help clarify the relative contributions of these factors.

Pressure analysis revealed that thoracic spine levels required higher mean inflation pressures (152.5 PSI) than lumbar levels (147.5 PSI). The significant relationship between pressure and age by decade (p=0.0014) and the absence of sex differences suggest that age-related changes in bone quality play a critical role in determining procedural pressures. The grouping of levels into subgroups also showed a significant relationship between spinal levels and pressure (p=0.044), further validating the relevance of the anatomical regionality [11].

While balloon volume correlated significantly with spinal levels and age (p= 0.0032 and p = 0.0137, respectively), no sex differences were observed. The mean balloon volume was greater in the lumbar spine (2.89 cc) than in the thoracic spine (2.42 cc), consistent with the larger vertebral body size in the lumbar region (Figure 6) [12].

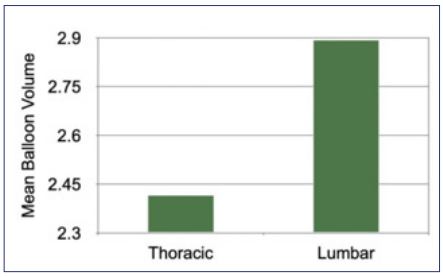

Figure 6: Balloon Volume in Relation to Location (Thoracic and Lumbar)

Analysis of patients with multiple dates of service (DOS) revealed no statistical significance. This could be attributed to the small sample size (n = 15). There was a trend toward older age in this subgroup. These findings suggest that more comprehensive studies are needed to evaluate whether secondary kyphoplasty procedures are influenced by predisposing factors, such as advancing age.

The limitations of this study include the small cohort size for certain analyses and the absence of direct bone quality measures.

Incorporating preoperative imaging data, such as quantitative vertebral height collapse or BMD, would strengthen future analyses. Furthermore, the significant relationship between cement volume, age, and sex warrants exploration to determine whether this is driven by anatomical differences or fracture severity.

In conclusion, this study underscores the importance of age, anatomical region, and procedural variables for kyphoplasty outcomes. The grouping of levels into subgroups demonstrates the need for nuanced anatomical considerations, particularly at the thoracolumbar junction. Advanced age was consistently associated with increased procedural requirements, suggesting that both fracture size and bone quality play pivotal roles. Future studies incorporating detailed preoperative assessments and larger sample sizes are necessary to refine kyphoplasty strategies and improve the outcomes.

Conclusion

This single-surgeon observation study shows that age, sex, and the involved spinal region significantly influence procedural components during kyphoplasty for OVCF. Both thoracic and lumbar fractures have different procedural requirements, with greater demands on the balloon and cement quantities at the lumbar levels. Variations in sex and ages emphasize the importance of personalized surgical planning in the optimization of patient outcomes. Future studies should investigate the long-term clinical implications of these observations regarding functional improvements and complications after kyphoplasty.

Acknowledgement

No outside funding was received in association with this work.

Conflict of Interest

EW: Nothing to disclose

SRH: Nothing to disclose

AMW: Consulting: Bolt Navigation (B)

Ethics Statement

All procedures performed in this study were in accordance with the ethical standards of the principles of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Data Access Statement

The deidentified data is stored on servers at Alta Orthopaedics.

References

[1] Donnally III CJ, DiPompeo CM, Varacallo MA. Vertebral Compression Fractures, In StatPearls. 2023; https://www.ncbi.nlm.nih.gov/books/NBK448171/.

[2] Kim HJ, Park S, Park SH, Park J, Chang BS, et al. Prevalence of Frailty in Patients with Osteoporotic Vertebral Compression Fracture and Its Association with Numbers of Fractures, Yonsei medical journal. 2018; 59: 317-324.

[3] Ong KL, Beall DP, Frohbergh M, Lau E, Hirsch JA. Were VCF patients at higher risk of mortality following the 2009 publication of the vertebroplasty "sham" trials?, Osteoporosis International. 2018; 29: 375-383.

[4] Anna Oleksik, Paul Lips, Alison Dawson, Michael E Minshall, Wei Shen, et al. Health-Related Quality of Life in Postmenopausal Women With Low BMD With or Without Prevalent Vertebral Fractures, Journal of Bone and Mineral Research. 2000; 15: 1384-1392.

[5] Cloft HJ, Jensen ME. Kyphoplasty: an assessment of a new technology, AJNR American journal of neuroradiology. 2007; 28: 200-203.

[6] Schmelzer-Schmied N, Cartens C, Meeder PJ, Dafonseca K. Comparison of kyphoplasty with use of a calcium phosphate cement and non-operative therapy in patients with traumatic non-osteoporotic vertebral fractures, European Spine Journal. 2009; 18: 624-629.

[7] Spiegl UJ, Scheyerer MJ, Osterhoff G, Grüninger S, Schnake KJ. Osteoporotic mid-thoracic vertebral body fractures: what are the differences compared to fractures of the lumbar spine?-a systematic review, European journal of trauma and emergency surgery. 2022; 48: 1639-1647.

[8] Sopon M, Oleksik V, Roman M, Cofaru N, Oleksik M, et al. Biomechanical Study of the Osteoporotic Spine Fracture: Optical Approach, Journal of personalized medicine. 2021; 11: 907.

[9] Nieves JW, Formica C, Ruffing J, Zion M, Garrett P, et al. Males have larger skeletal size and bone mass than females, despite comparable body size. Journal of bone and mineral research, the official journal of the American Society for Bone and Mineral Research. 2005; 20: 529-535.

[10] Marcucci G, Brandi ML. Kyphoplasty and vertebroplasty in the management of osteoporosis with subsequent vertebral compression fractures, Clinical cases in mineral and bone metabolism. 2010; 7: 51-60.

[11] Park SK, Park JG, Kim BS, Huh JD, Kang H. Thoracolumbar junction: morphologic characteristics, various variants and significance, The British journal of radiology. 2016; 89: 20150784.

[12] Waxenbaum JA, Reddy V, Williams C, Bennett Futterman. Anatomy, Back, Lumbar Vertebrae, StatPearls. 2025; https://www.ncbi.nlm.nih.gov/books/NBK459278/.