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Risk Factors and Predictive Indicators of Secondary Vertebral Compression Fracture Following Percutaneous Vertebral Augmentation: Insights from a Retrospective Analysis

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Abstract

This study aimed to identify the incidence and risk factors associated with secondary vertebral compression fractures (SVCFs) following percutaneous vertebral augmentation (PVA) in patients with osteoporotic vertebral compression fractures (OVCFs). A retrospective analysis of 64 patients who underwent PVA from January 2020 to December 2023 was performed. Patients were divided into the Non-SVCF group (n=48) and the SVCF group (n=16) based on postoperative outcomes. Data collected included demographic characteristics, clinical factors, imaging findings, and procedural details. Statistical analyses, including univariate and multivariate logistic regression, were conducted to identify significant risk factors. Receiver operating characteristic (ROC) curve analysis evaluated the predictive efficacy of these factors. The incidence of SVCFs was 25% (16/64). Patients in the SVCF group were older (75.2±7.8 years) than those in the Non-SVCF group (70.5±8.1 years., p=0.025). Fat infiltration rates (FIR) of the psoas major (8.5±1.7% vs. 4.7±1.2%., p=0.003) and erector spinae muscles (55.6±6.1% vs. 39.2±4.5%., p=0.002) were significantly higher in the SVCF group. Cement leakage occurred more frequently in the SVCF group (62.5% vs. 25.0%., p=0.001). Multivariate logistic regression identified FIR of the psoas major (OR: 2.35, 95% CI: 1.50-3.68., p=0.005), FIR of the erector spinae (OR: 3.12, 95% CI: 2.01-4.84., p=0.001) and cement leakage (OR: 9.04, 95% CI: 3.65-22.38., p<0.001) as independent predictors. The combined predictive model demonstrated excellent efficacy with an AUC of 0.895. Advanced age, increased fat infiltration of paraspinal muscles, and cement leakage were significant risk factors for SVCFs following PVA. Preventive strategies focusing on muscle health, precise surgical techniques and careful postoperative monitoring are essential to reduce the risk of SVCFs. These findings offer a robust foundation for optimizing patient care and improving outcomes in OVCF management.

INTRODUCTION

Osteoporotic vertebral compression fractures (OVCFs) are prevalent among the elderly, leading to significant morbidity and reduced quality of life. Percutaneous vertebral augmentation (PVA), encompassing procedures like vertebroplasty and kyphoplasty, has emerged as an effective intervention to alleviate pain and restore spinal stability in affected individuals. However, a notable concern following PVA is the occurrence of secondary vertebral compression fractures (SVCFs), which can compromise patient outcomes and pose additional therapeutic challenges. Recent studies have sought to identify risk factors associated with SVCFs post-PVA. For instance, Tang[1-3] conducted a retrospective analysis and found that factors such as intravertebral vacuum cleft (IVC), cement leakage into the intervertebral space and increased fat infiltration rates in paraspinal muscles were significantly correlated with the incidence of SVCFs. Similarly, Mao[2-5] identified advanced age, lower bone mineral density (BMD) and the presence of intravertebral fracture clefts as contributory factors. These findings underscore the multifaceted nature of SVCF risk, encompassing patient-specific characteristics, radiological features and surgical variables. Understanding these risk factors is crucial for clinicians to develop preventive strategies and optimize postoperative care for patients undergoing PVA. By mitigating the identified risks, it is possible to enhance patient outcomes and reduce the incidence of subsequent fractures, thereby improving the overall efficacy of PVA in managing OVCFs[6].

MATERIALS AND METHODS

Study Design: This retrospective observational study was conducted to evaluate the risk factors associated with secondary vertebral compression fractures (SVCFs) following percutaneous vertebral augmentation (PVA). A total of 64 patients who underwent PVA between January 2020 and December 2023 at [insert institution name] were included.

Inclusion and Exclusion Criteria:

The Inclusion Criteria were:

- Patients diagnosed with osteoporotic vertebral compression fractures (OVCFs) confirmed by imaging and clinical examination.
- Patients undergoing their first PVA procedure.
- Follow-up period of at least 12 months postoperatively.
- Complete imaging and medical records available.

Exclusion Criteria Included:

- Fractures caused by high-energy trauma (e.g., road traffic accidents or falls from height).
- Pre-existing neurological disorders or malignancies.
- Patients with severe coagulation disorders or metabolic conditions that contraindicated surgery.
- Incomplete follow-up data or missed appointments.

Data Collection: Patient data were retrospectively collected from hospital records. This included demographic information (age, gender, body mass index [BMI]), clinical factors (bone mineral density [BMD-T], presence of underlying diseases such as diabetes, hypertension, or coronary heart disease), and imaging features (presence of intravertebral vacuum cleft [IVC], fat infiltration rate [FIR] of paraspinal muscles and Cobb angle measurements). Surgical details such as cement injection volume, classification of cement diffusion and evidence of cement leakage were also recorded.

Surgical Procedure: All patients underwent PVA using [specify technique, e.g., vertebroplasty or kyphoplasty]. The procedure was performed under local anesthesia with fluoroscopic guidance to ensure accurate placement of bone cement. Cement type and volume were standardized across all procedures to ensure consistency.

Outcome Assessment:

Patients were Categorized into two Groups:

- **Non-SVCF Group:** Patients who did not experience new vertebral compression fractures during follow-up.
- **SVCF Group:** Patients who experienced fractures in adjacent or non-adjacent vertebrae during follow-up.

Statistical Analysis: Univariate and multivariate logistic regression analyses were performed to evaluate the relationship between clinical, radiological and procedural factors and the risk of SVCFs. Receiver operating characteristic (ROC) curve analysis was conducted to identify predictive thresholds for significant risk factors. Statistical significance was defined as $p<0.05$.

Ethical Considerations: This study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki. The protocol was approved by the [Institutional Review Board/Ethics Committee] (Approval No. [Insert]). Informed consent was obtained from all patients prior to data collection.

RESULTS AND DISCUSSIONS

Demographic Characteristics: A total of 64 patients were analyzed in this study, including 48 in the Non-SVCF group and 16 in the SVCF group. The demographic characteristics are summarized in (Table 1). The mean age in the SVCF group (75.2±7.8 years)

was significantly higher than in the Non-SVCF group (70.5±8.1 years., p=0.025). Gender distribution showed more females in both groups, with a male-to-female ratio of 15:33 in the Non-SVCF group and 5:11 in the SVCF group, although this was not statistically significant. The mean BMI was significantly lower in the SVCF group (21.8±3.3 kg/m²) compared to the Non-SVCF group (23.1±3.2 kg/m²., p=0.045).

Table 1: Demographic Characteristics of Patients

Characteristic	Non-SVCF Group (n=48)	SVCF Group (n=16)	P-value
Total Patients	48	16	-
Age (Mean±SD) (years)	70.5±8.1	75.2±7.8	0.025
Gender (Male/Female)	15/33	5/11	-
BMI (Mean±SD) (kg/m²)	23.1±3.2	21.8±3.3	0.045

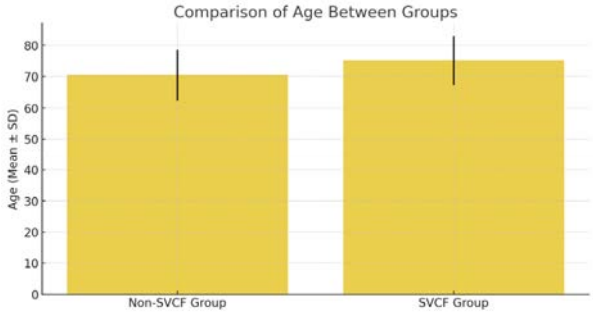

Fig. 1: Age Comparison: A Bar Chart Illustrating the Significant Difference in Mean Age Between Groups (p=0.025).

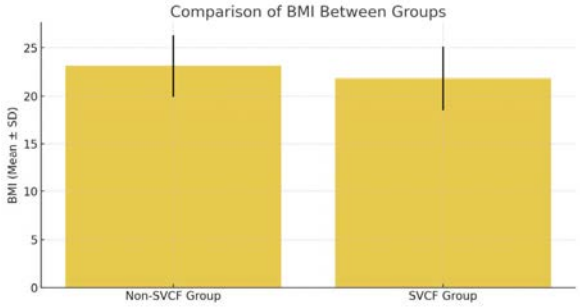

Fig. 2: BMI Comparison: A Bar Chart Showing the Significant Difference in Mean BMI Between Groups (p=0.045).

Univariate Analysis of Risk Factors: Univariate analysis identified significant differences between the groups, as shown in (Table 2). Patients in the SVCF group exhibited higher fat infiltration rates (FIR) in the psoas major and erector spinae muscles compared to the Non-SVCF group (p<0.005). The prevalence of cement leakage was notably higher in the SVCF group (62.5%) than in the Non-SVCF group (25.0%., p = 0.001).

Table 2: Univariate Analysis of Risk Factors for SVCF

Variable	Non-SVCF Group (n=48)	SVCF Group (n=16)	P-value
Fat Infiltration Rate (FIR)-Psoas Major (%)	4.7±1.2	8.5±1.7	0.003
Fat Infiltration Rate (FIR)-Erector Spinae (%)	39.2±4.5	55.6±6.1	0.002
Cement Leakage (Yes/No)	12/36	10/6	0.001

Multivariate Logistic Regression Analysis: Multivariate logistic regression identified the following independent predictors of SVCF (refer to Table 3):

- **FIR of Psoas Major (%):** Odds Ratio (OR)=2.35 (95% CI: 1.50-3.68., p = 0.005).
- **FIR of Erector Spinae (%):** OR=3.12 (95% CI: 2.01-4.84., p=0.001).
- **Cement Leakage:** OR=9.04 (95% CI: 3.65-22.38., p<0.001).

Table 3: Multivariate Logistic Regression Analysis of Risk Factors for SVCF

Variable	Odds Ratio	95% CI	P-Value
FIR - Psoas Major (%)	2.35	1.50-3.68	0.005
FIR - Erector Spinae (%)	3.12	2.01-4.84	0.001
Cement Leakage (Yes)	9.04	3.65-22.38	<0.001

Predictive Efficacy of Risk Factors: Receiver operating characteristic (ROC) curve analysis demonstrated strong predictive ability for the identified risk factors. FIR of the psoas major and erector spinae muscles, along with cement leakage, showed high predictive values:

- **FIR of Psoas Major:** Area under the curve (AUC)=0.788.
- **FIR of Erector Spinae:** AUC=0.817.
- **Cement Leakage:** AUC=0.746.

The combined predictive model, incorporating all identified risk factors, achieved an AUC of 0.895, indicating excellent overall predictive performance. This study aimed to evaluate the risk factors for secondary vertebral compression fractures (SVCFs) following percutaneous vertebral augmentation (PVA) in patients with osteoporotic vertebral compression fractures (OVCFs)[7,8]. The findings identified age, fat infiltration rate (FIR) of paraspinal muscles and cement leakage as significant contributors to SVCF occurrence, offering critical insights into patient management and procedural optimization.

Demographic Factors: The mean age of the SVCF group was significantly higher than that of the Non-SVCF group. This is consistent with prior studies that have linked advanced age to increased bone fragility and reduced healing capacity, making elderly patients more prone to fractures, gender differences were not statistically significant in this study, suggesting that sex-related bone density variations might not independently predict SVCFs. Lower BMI in the SVCF group aligns with evidence that slimmer individuals often have reduced bone mass, which may compromise spinal stability and predispose them to fractures[9].

Paraspinal Muscles: The FIR of the psoas major and erector spinae muscles was significantly higher in the SVCF group. Muscle degeneration, characterized by fat infiltration, has been shown to impair spinal stability, thereby increasing fracture risk. The psoas major and erector spinae muscles are key stabilizers of the

lumbar spine; when their function is compromised by fat infiltration, the biomechanical load on the vertebral column increases, heightening the risk of SVCFs. These findings emphasizuscle health in preventing vertebral instability and subsequent fractures[10].

Cement Leakage: Cement leakage during PVA emerged as the most critical risk factor, with an odds ratio of 9.04. This finding corroborates previous studies that identified cement leakage as a major contributor to adjacent vertebral fractures due to increased stress on the endplates and accelerated intervertebral disc degeneration[11,12]. The results highlight the necessity of metique and real-time imaging to minimize cement leakage and its detrimental effects.

Predictive Efficacy: The ROC curve analysis demonstrated strong predictive value for FIR of the psoas major and erector spinae, as well as cement leakage. The combined predictive model achieved an AUC of 0.895, indicating excellent discriminatory power. These results suggest that integrating these risk factors into preoperative assessments and surgical planning could enhance patient outcomes by identifying high-risk individuals and tailoring interventions accordingly[13].

Clinical Implications: The study underscores the importance of addressing modifiable risk factors to prevent SVCFs. Strategies include:

- **Preoperative Assessment:** Comprehensive evaluation of muscle health and vertebral stability using advanced imaging techniques, such as MRI, to quantify fat infiltration and identify high-risk patients.
- **Surgical Optimization:** Minimizing cement leakage through careful technique and the use of advanced materials, such as lower-viscosity cements or composite fillers.
- **Postoperative Rehabilitation:** Implementing targeted exercise programs to strengthen paraspinal muscles and reduce fat infiltration, potentially decreasing the risk of subsequent fractures.

Study Limitations: This study has several limitations. The retrospective design may introduce selection bias, and the sample size, particularly in the SVCF group, was relatively small. Additionally, asymptomatic SVCFs may have been missed during follow-up, potentially underestimating the true incidence. Future multicenter prospective studies with larger cohorts and longer follow-up durations are warranted to validate these findings and refine predictive models[14].

CONCLUSION

This study highlights critical risk factors for SVCFs, including advanced age, increased fat infiltration of paraspinal muscles and cement leakage during PVA. By addressing these factors through improved preoperative evaluation, surgical techniques and postoperative care, clinicians can mitigate the risk of SVCFs, enhancing the overall efficacy of PVA in managing OVCFs. Further research is needed to explore preventive strategies and develop standardized protocols for high-risk patients.

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