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Original article

The Utility of Bone Scintigraphy in the Surgical Management of Lumbar Spine Fractures in the Geriatric Population

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Abstract

Background: Osteoporotic vertebral fractures are a common cause of pain, disability, and reduced mobility in older adults. Conventional imaging techniques may not accurately identify metabolically active fractures or distinguish symptomatic lesions from chronic degenerative changes. Bone scintigraphy offers functional assessment of bone metabolism and may improve preoperative evaluation and surgical planning.

Objective: To investigate the clinical value of preoperative bone scintigraphy in patients with osteoporotic lumbar vertebral fractures by evaluating fracture distribution, correlating scintigraphic findings with histopathological changes, and assessing their relationship with postoperative surgical outcomes.

Methods: This retrospective study included 114 patients with osteoporotic lumbar vertebral fractures who underwent decompression and instrumented spinal fusion between 2015 and 2021.

Demographic characteristics, bone mineral density, fracture location, bone scintigraphy findings, histopathological results, and postoperative outcomes were reviewed. Scintigraphic uptake patterns were compared with histopathological findings and 12-month radiographic fusion status. Associations between preoperative tracer uptake and postoperative complications were also analyzed.

Results: The cohort was predominantly female with a mean T-score of −2.9, indicating severe osteoporosis. Fractures most commonly involved the L4–L5 vertebrae (62%), with the highest incidence observed in patients aged 75–84 years. Bone scintigraphy identified metabolically active vertebral lesions that were not evident on conventional radiographs. Areas of increased tracer uptake corresponded with micro-trabecular fractures and chronic inflammatory changes on histopathology. At 12 months, the overall fusion rate was 92%. Higher preoperative tracer uptake was associated with improved fusion, fewer cases of hardware loosening and revision surgery, whereas lower uptake was associated with an increased risk of pseudarthrosis.

Conclusions: Preoperative 99mTc-MDP bone scintigraphy provides valuable functional information that complements conventional imaging by identifying biologically active fractures and predicting postoperative healing. Incorporating metabolic imaging into the preoperative assessment may improve surgical planning and outcomes in elderly patients with osteoporotic lumbar vertebral fractures.

Key words. Osteoporosis. Lumbar fracture. bone scientigraphy. Geriatric population. Degenerative spine.

Introduction

Osteoporotic lumbar vertebral fractures are a major cause of pain, disability, and loss of functional independence among older adults. As life expectancy continues to increase, the prevalence of osteoporosis-related spinal fractures has risen substantially, creating an increasing burden on healthcare systems worldwide. Reduced bone mineral density compromises vertebral strength and adversely affects the stability of spinal instrumentation, making surgical management particularly challenging in elderly patients. Instrumented fusion can provide pain relief and restore spinal stability; however, poor bone quality increases the risk of pedicle screw loosening, pseudarthrosis, implant failure, and the need for revision surgery.[1]

Accurate identification of the symptomatic vertebral level is essential before surgical intervention. Conventional imaging modalities, including plain radiography and computed tomography (CT), provide excellent anatomical detail but often fail to distinguish acute painful fractures from chronic deformities or degenerative changes. Magnetic resonance imaging (MRI) is highly sensitive for detecting bone marrow edema and soft-tissue abnormalities, yet its diagnostic utility may be reduced in patients with metallic implants, contraindications to MRI, or equivocal findings.[2],[3]

Nuclear medicine techniques complement structural imaging by providing functional information about bone metabolism. Technetium-99m methylene diphosphonate (99mTc-MDP) bone scintigraphy is highly sensitive for detecting increased osteoblastic activity associated with acute fractures, delayed healing, stress injuries, and inflammatory processes.

.Functional tracer uptake can be accurately correlated with CT-defined structural changes, allowing clinicians to identify the vertebral segments responsible for the patient's symptoms while excluding inactive chronic lesions. This hybrid imaging approach is particularly valuable in elderly

patients with multilevel degenerative disease, where conventional imaging findings frequently exceed clinical symptomatology.[6–8]

Preoperative assessment of metabolic activity may also provide important information regarding the biological environment of osteoporotic bone. Increased tracer uptake reflects active bone remodeling and may indicate fracture healing potential, whereas reduced metabolic activity may suggest chronic nonunion or poor biological response. These findings can influence surgical planning by guiding the selection of fusion levels, optimizing fixation strategies, and identifying patients who may benefit from augmented pedicle screw fixation or osteoporosisdirected therapy.[9–12]

Osteoporotic vertebral fractures are frequently underdiagnosed because radiographic findings may not accurately reflect fracture acuity or identify the pain-generating vertebral level. While CT provides excellent visualization of cortical disruption, it cannot reliably distinguish acute from chronic fractures. MRI remains the reference standard for identifying bone marrow edema and associated soft-tissue abnormalities; however, image quality may be compromised by metallic implants, patient intolerance, or contraindications such as cardiac pacemakers.[3,13]

postoperative changes while reducing false-positive findings associated with planar scintigraphy alone. Several studies have shown that CT provides superior diagnostic confidence and significantly influences clinical management in patients with persistent spinal pain.[6,7]

Methodology

Study Design

This retrospective cohort study was conducted at a tertiary care hospital PIMS Islamabad, to evaluate the clinical value of preoperative technetium-99m methylene diphosphonate (99mTc-MDP) bone scintigraphy in elderly patients undergoing lumbar decompression and instrumented fusion for osteoporotic vertebral fractures. Medical records of patients treated between January 2015 and December 2021 were retrospectively reviewed. The study protocol was approved by the Institutional Review Board, and all patient information was anonymized prior to analysis in accordance with institutional ethical guidelines.

Patient Selection

Patients aged 65 years or older with symptomatic osteoporotic lumbar vertebral fractures who underwent lumbar decompression and posterior instrumented fusion were eligible for inclusion. All patients had undergone preoperative 99mTc-MDP bone scintigraphy, performed within 30 days before surgery, as part of the routine preoperative assessment. Osteoporosis was confirmed using dual-energy X-ray absorptiometry (DXA), and only patients with documented bone mineral density measurements were included in the analysis.

Patients were excluded if they had metastatic spinal disease, primary bone tumors, spinal infections, pathological fractures unrelated to osteoporosis, or metabolic bone disorders other than age-related osteoporosis. Patients with incomplete clinical records, unavailable imaging studies, or less than 12 months of postoperative follow-up were also excluded.

Bone Scintigraphy and CT Protocol

All patients received an intravenous injection of 740–925 MBq of 99mTc-MDP. Delayed planar whole-body and lumbar spine images were acquired approximately 3 hours after radiotracer

administration using a dual-head gamma camera. CT imaging of the lumbar spine was subsequently performed to improve anatomical localization of areas demonstrating increased tracer uptake.

Scintigraphic images were independently reviewed by experienced nuclear medicine physicians, while CT images were interpreted by musculoskeletal radiologists. The metabolic findings were correlated with anatomical abnormalities identified on CT and with the patient's clinical presentation to identify metabolically active vertebral lesions.

Surgical Procedure

All patients underwent posterior lumbar decompression followed by pedicle screw fixation and instrumented fusion. Surgical planning was individualized according to fracture morphology, neurological status, spinal stability, and preoperative imaging findings. In patients with severely osteoporotic bone, augmentation techniques were employed at the discretion of the operating surgeon to improve fixation strength and reduce the risk of implant failure.

Data Collection

Clinical and radiological data were extracted from electronic medical records. Demographic variables included age, sex, bone mineral density, and fracture characteristics. Operative details, scintigraphic findings, neurological status, and preoperative pain scores were recorded.
Postoperative imaging was reviewed to assess fusion status, implant integrity, pedicle screw loosening, and adjacent segment pathology. Clinical outcomes, including pain improvement, complications, and the need for revision surgery, were documented throughout follow-up.

Outcome Measures

The primary outcome of the study was to determine the association between preoperative scintigraphic activity and successful spinal fusion following lumbar instrumentation. Secondary outcomes included postoperative pain relief, hardware loosening, pseudarthrosis, implant- related complications, revision surgery, and radiographic evidence of successful arthrodesis. All patients underwent routine clinical and radiological follow-up for a minimum period of 12 months after surgery.

Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics 21. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on data distribution, whereas categorical variables were presented as frequencies and percentages. Multivariable logistic regression analysis was used to evaluate the relationship between preoperative scintigraphic activity and postoperative outcomes while adjusting for potential confounding factors, including age, sex, bone mineral density, fracture characteristics, and comorbidities. A two-sided P value <0.05 was considered statistically significant.

Results

Demographic and Fracture Pattern Distribution

A total of 114 patients met the study inclusion criteria. The cohort was predominantly female, with a mean DXA T-score of −2.9, consistent with advanced osteoporosis. The mean patient age was within the elderly population, with the highest incidence of vertebral compression fractures observed among patients aged 75–84 years. Lumbar vertebral fractures most frequently involved

the L4 and L5 segments, accounting for 62% of all identified fracture sites. Multilevel degenerative disc disease commonly coexisted with osteoporotic fractures in this population.

Preoperative 99mTc-MDP bone scintigraphy with SPECT/CT identified increased metabolic activity not only at the symptomatic vertebral fractures but also at adjacent lumbar segments that appeared unremarkable on conventional radiographs. These occult hypermetabolic lesions suggested ongoing bone remodeling despite the absence of structural abnormalities on plain imaging, demonstrating the added diagnostic value of metabolic imaging in elderly patients with complex spinal pathology.

Bone Scintigraphy Findings and Histopathological Correlation

Intraoperative bone biopsy specimens obtained from selected patients demonstrated a strong correlation between regions of intense radiotracer uptake and underlying histopathological abnormalities. Areas showing increased scintigraphic activity were characterized by microtrabecular fractures, active bone remodeling, and chronic inflammatory cellular infiltration. These findings indicate that increased tracer accumulation reflects biologically active osseous repair rather than purely structural changes.

The concordance between scintigraphic findings and histopathology supports the role of 99mTcMDP CT as a functional imaging biomarker capable of identifying metabolically active fractures. Furthermore, quantitative tracer uptake appeared to reflect the biological capacity for bone healing, suggesting potential prognostic value during preoperative assessment.

Postoperative Outcomes

Clinical and radiological follow-up at 12 months demonstrated a 92% successful fusion rate following lumbar decompression and instrumented fusion. Patients exhibiting high preoperative scintigraphic tracer uptake achieved significantly better postoperative outcomes than those with lower metabolic activity.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Value
Total patients	114
Predominant sex	Female
Mean DXA T-score	−2.9
Study population	≥65 years
Most common fracture levels	L4–L5
L4–L5 fracture involvement	62%
Peak age group	75–84 years
Imaging modality	99mTc-MDP Bone Scintigraphy with SPECT/CT.

Table 2. Bone Scintigraphy and Histopathological Findings

Parameter	Observation
Increased tracer uptake	Corresponded with micro-trabecular fractures
Histopathology	Chronic inflammatory cellular infiltration
Occult adjacent hypermetabolic lesions	Present despite normal plain radiographs
Clinical significance	Indicates active bone remodeling
Potential biomarker	Predictive of osseous healing potential

Table .3. postoperative outcome

Outcome	Result
Fusion rate (12 months)	92%
Hardware loosening	Lower in high tracer uptake group
Revision surgery	Reduced in high tracer uptake group
Pseudarthrosis	Higher in low tracer uptake group Table 3. Postoperative Outcomes
Screw pull-out	Less frequent in high tracer uptake group
Symptomatic pedicle breach	Less frequent in high tracer uptake group

Figure 1

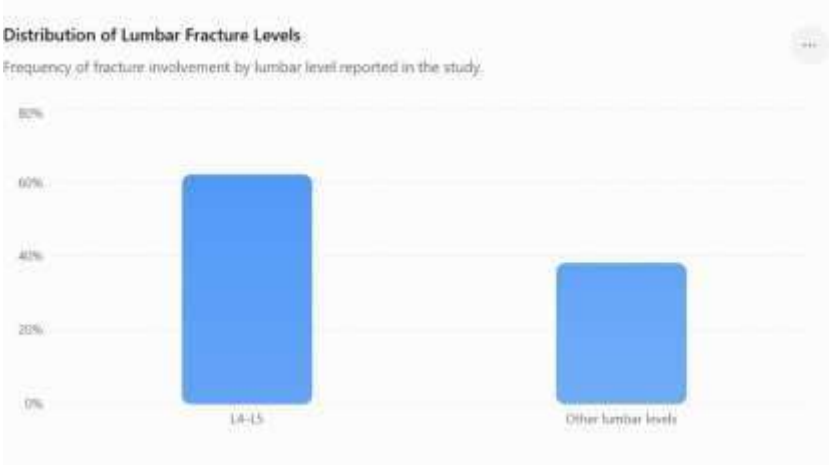
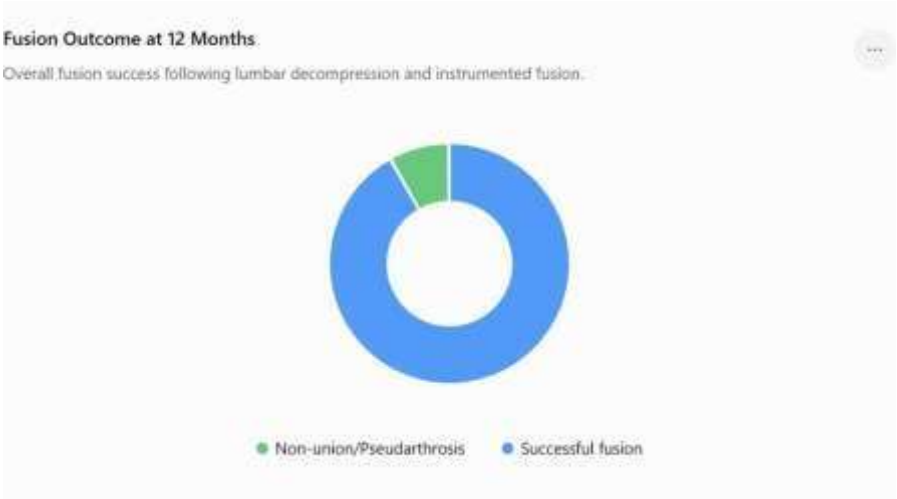


Figure 2.



Discussion

The present study highlights the value of preoperative 99mTc-MDP bone scintigraphy with CT as a complementary imaging modality in the evaluation of elderly patients with osteoporotic lumbar vertebral fractures undergoing decompression and instrumented fusion. By combining functional assessment of bone metabolism with anatomical localization, SPECT/CT provides information that cannot be obtained from conventional CT or MRI alone. In our cohort, metabolically active vertebral lesions identified on scintigraphy corresponded well with symptomatic fracture levels and assisted in defining the extent of surgical stabilization. These findings support previous reports demonstrating that CT improves lesion localization and diagnostic confidence in patients with complex spinal pathology.[14]

Conventional radiography and CT primarily depict structural abnormalities and may not accurately differentiate acute symptomatic fractures from chronic osteoporotic deformities or multilevel degenerative changes. MRI is highly sensitive for detecting bone marrow edema and neural compression but may be contraindicated or limited in patients with implanted metallic devices or severe degenerative disease. In contrast, bone scintigraphy detects increased osteoblastic activity associated with active bone remodeling, enabling identification of metabolically active fractures that may be occult or equivocal on structural imaging. [15]

Increased tracer uptake at the fractured vertebral level reflects active bone turnover and may indicate ongoing biological repair, the limited uptake may suggest chronic injury or impaired healing potential. This information can assist surgeons in selecting the most appropriate fusion levels and determining whether additional fixation strategies, such as cement augmentation or extended instrumentation, should be considered in patients with severe osteoporosis. This study

was not designed to establish a causal relationship between scintigraphic intensity and surgical outcomes, the findings suggest that metabolic imaging may improve patient selection and optimize fixation strategies by identifying biologically active lesions.[16]

The results should also be interpreted in the context of several limitations inherent to bone scintigraphy. The technique demonstrates excellent sensitivity, its specificity remains relatively limited because increased tracer accumulation may occur in degenerative facet arthropathy, inflammatory arthropathies, postoperative remodeling, infection, or neoplastic disease.[17,18]

Despite encouraging findings, several limitations of the present study should be acknowledged. First, its retrospective single-center design introduces the possibility of selection bias and limits the generalizability of the results. Second, quantitative analysis of scintigraphic tracer uptake was limited by the absence of universally accepted reference values defining clinically meaningful metabolic activity. Third, postoperative outcomes were assessed over a minimum follow-up period of 12 months, which may not fully capture delayed hardware failure or adjacent segment degeneration. Finally, although associations between metabolic activity and surgical outcomes were observed, this study cannot establish definitive prognostic thresholds because of its observational design.

The investigations should focus on prospective multicenter studies with larger patient populations to validate the prognostic significance of quantitative SPECT/CT parameters. The development of standardized uptake thresholds may enable clinicians to distinguish physiological bone remodeling from pathological instability more reliably and improve reproducibility across institutions. Integrating metabolic imaging with bone mineral density measurements, finite element biomechanical modeling, and advanced artificial intelligence–

based image analysis may enhance individualized risk stratification and guide precision surgical planning for osteoporotic spinal fractures.[19.20]

Conclusion

In conclusion, preoperative 99mTc-MDP bone scintigraphy with CT provides valuable complementary information in elderly patients undergoing lumbar instrumentation for osteoporotic vertebral fractures. By identifying metabolically active fractures and improving anatomical localization, hybrid imaging can enhance preoperative decision-making beyond conventional structural imaging alone. Although further prospective validation is required, incorporating metabolic assessment into the preoperative evaluation may facilitate more

individualized surgical planning, improve fixation strategies, and ultimately contribute to better clinical and radiological outcomes in patients with osteoporotic spinal disease.

References.

1. Chamarthy M, Freeman LM. Bone scintigraphy and SPECT/CT in orthopedic imaging. Radiographics. 2010;30(6):1757-68. doi:10.1148/rg.306105520.
2. Van den Wyngaert T, Strobel K, Kampen WU, Kuwert T, van der Bruggen W, Mohan HK, et al. The EANM practice guidelines for bone scintigraphy. Eur J Nucl Med Mol Imaging. 2016;43(9):1723-38. doi:10.1007/s00259-016-3415-4.
3. Kato S, Murray JC, Kwon BK, Schroeder GD, Vaccaro AR, Fehlings MG. The efficacy of MRI in the diagnosis of osteoporotic vertebral fractures. J Orthop Sci. 2019;24(2):185-91.

4. Scheyerer MJ, Zimmermann SM, Bouaicha S, Simmen HP, Wanner GA, Werner CM. Location and morphology of osteoporotic vertebral fractures. Eur Spine J. 2014;23(Suppl 6):S762-S767.

5. Hirsch JA, Beall DP, Chambers MR, et al. Management of vertebral compression fractures: current concepts and future directions. J Neurointerv Surg. 2023;15(1):9-16.

6. Piñera AR, Duran C, Lopez B, et al. Instrumented lumbar fusion in elderly patients with osteoporosis. Neurosurg Focus. 2011;31(4):E8.

7. Ahmadzadehfar H, Sabet A, Wilhelm K, et al. The role of SPECT/CT in musculoskeletal disorders. Clin Nucl Med. 2014;39(11):e486-e493.

8. Ross JC, O'Connor MK, Kemp BJ. Radiation dose optimization in hybrid SPECT/CT imaging. Eur J Radiol. 2019;118:9-16.

9. Blake GM, Fogelman I. The role of nuclear medicine in the diagnosis of metabolic bone disease. Semin Nucl Med. 2001;31(1):28-49.

10. Palestro CJ. Radionuclide imaging of musculoskeletal disorders. Radiology. 2016;279(3):660-78. doi:10.1148/radiol.2016151724.

11 Mankin HJ, Mankin CJ, Simon MA. The hazards of biopsy in patients with malignant primary bone and soft-tissue tumors. J Bone Joint Surg Am. 1996;78(5):656-63.

12. Kanis JA, McCloskey EV, Johansson H, Cooper C, Rizzoli R, Reginster JY. European guidance for the diagnosis and management of osteoporosis in postmenopausal women. Osteoporos Int. 2013;24(1):23-57. doi:10.1007/s00198-012-2074-y.

13. Cosman F, de Beur SJ, LeBoff MS, Lewiecki EM, Tanner B, Randall S, et al. Clinician's guide to prevention and treatment of osteoporosis. Osteoporos Int. 2014;25(10):2359-81.

14. Lewiecki EM, Binkley N, Morgan SL, et al. Best practices for dual-energy Xray absorptiometry measurement and reporting. J Clin Densitom. 2016;19(2):127-40.

15. Mallepally AR, Rajasekaran S, Kanna RM, et al. Pedicle screw fixation in osteoporotic spine: current concepts and recent advances. Global Spine J. 2023;13(8):2148-59.

16. Buckley JM, Cheng L, Loo K, Slyfield C. Quantitative computed tomography and the biomechanics of the osteoporotic spine. Spine (Phila Pa 1976). 2007;32(2):E16E22. doi:10.1097/01.brs.0000251017.40444.5d.

17. Genant HK, Wu CY, van Kuijk C, Nevitt MC. Vertebral fracture assessment using a semiquantitative technique. J Bone Miner Res. 1993;8(9):1137-48. doi:10.1002/jbmr.5650080915.

18. Bydon M, De la Garza-Ramos R, Macki M, et al. Lumbar fusion versus nonoperative management for osteoporotic vertebral compression fractures: current evidence and future directions. World Neurosurg. 2014;82(6):e719-e725. doi:10.1016/j.wneu.2014.07.018.

19. Even-Sapir E. Imaging of malignant bone involvement by morphologic, scintigraphic, and hybrid modalities. J Nucl Med. 2005;46(8):1356-67.

20. Söderlund V, Larsson SA. SPECT/CT in benign skeletal disorders: increasing diagnostic accuracy in orthopedic imaging. Acta Radiol. 2013;54(6):673-81. doi:10.1177/0284185113483150.