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Original Article/นิพนธ์ต้นฉบับ

Comparison Between Magnetic Resonance Imaging of Spine and Dual Energy X-Ray Absorptiometry Scan for Assessment Bone Mineral Density in Degenerative Spine Patients in Bhumibol Adulyadej Hospital: A Single-Center Study

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Abstract

Purpose: To evaluate the diagnostic efficacy of the vertebral bone quality (VBQ) score in diagnosing osteoporosis.

Method: A retrospective analysis was conducted on patients who underwent both dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging of the lumbosacral spine. The VBQ score was compared with T-scores and Z-scores using the Pearson correlation coefficient to assess its diagnostic performance for osteoporosis.

Results: A total of 161 patients with degenerative spine disease were included. The mean age was 71.4 ± 10.1 years, comprising 122 females (75.8%) and 39 males (24.2%). The VBQ score showed a moderate negative correlation with spine and hip T-scores ($r = -0.356$ and -0.341, respectively). Receiver operating characteristic curve analysis for bone mineral density (BMD) and VBQ scores demonstrated an area under the curve of 0.652 (95% CI, 0.555–0.750) for osteopenia and 0.674 (95% CI, 0.558–0.790) for osteoporosis. For osteoporosis, the VBQ score had a positive predictive value of 32% (95% CI, 28.14%–36.23%), a negative predictive value of 92% (95% CI, 76.02%–98.01%), and an accuracy of 47.6% (95% CI, 37.78%–57.59%).

Conclusion: The VBQ score is a useful tool for primary screening of osteoporosis but cannot replace DXA scans. A VBQ score < 3.1 can be used to exclude osteoporosis, whereas a VBQ score ≥ 3.2 indicates the need for further evaluation with DXA, the current gold standard.

Key words: vertebral bone quality, Dual Energy X-ray Absorptiometry Scan, bone mineral density, Magnetic Resonance Imaging, degenerative spine

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บทคัดย่อ

เปรียบเทียบระหว่างภาพถ่ายรังสีของกระดูกสันหลังด้วยคลื่นแม่เหล็กไฟฟ้า และเครื่องตรวจวิเคราะห์ความหนาแน่นของกระดูก ในการตรวจวัดความหนาแน่นของมวลกระดูกของผู้ป่วยกระดูกสันหลังเสื่อมในโรงพยาบาลภูมิพลอดุลยเดช

วัตถุประสงค์: เพื่อประเมินประสิทธิภาพของคะแนนคุณภาพกระดูกสันหลัง (Vertebral Bone Quality: VBQ) ในการวินิจฉัยโรคกระดูกพรุน

วิธีการ: การศึกษาย้อนหลังได้รวบรวมผู้ป่วยที่ได้รับการตรวจวัดความหนาแน่นของมวลกระดูกด้วยเครื่องเอกซเรย์ดูอัลเอนเนอร์จี (Dual-Energy X-ray Absorptiometry: DXA) และการตรวจด้วยคลื่นแม่เหล็กไฟฟ้าบริเวณกระดูกสันหลังส่วนเอวและกระเบนเหน็บ (lumbosacral spine) คะแนน VBQ ถูกนำมาเปรียบเทียบกับค่า T-score และ Z-score โดยใช้ค่าสัมประสิทธิ์สหสัมพันธ์เพียร์สัน (Pearson correlation coefficient) เพื่อแสดงประสิทธิภาพในการวินิจฉัยโรคกระดูกพรุน

ผลการศึกษา: ผู้ป่วยทั้งหมด 161 ราย เป็นผู้ป่วยโรคเสื่อมของกระดูกสันหลัง อายุเฉลี่ย 71.4 ± 10.1 ปี เป็นเพศหญิง 122 ราย (75.8%) และเพศชาย 39 ราย (24.2%) คะแนน VBQ เมื่อเปรียบเทียบกับค่า T-score ของกระดูกสันหลังและสะโพกพบว่ามีความสัมพันธ์ในระดับปานกลาง ($r = -0.356$ และ -0.341 ตามลำดับ) การวิเคราะห์เส้นโค้ง ROC เพื่อประเมินค่าความหนาแน่นของมวลกระดูก (BMD) และคะแนน VBQ ในแง่พื้นที่ใต้เส้นโค้ง (AUC) พบว่าในการวินิจฉัยภาวะกระดูกบาง (osteopenia) มีค่า AUC เท่ากับ 0.652 (95% CI, 0.555–0.750) และในโรคกระดูกพรุนมีค่า AUC เท่ากับ 0.674 (95% CI, 0.558–0.790) สำหรับโรคกระดูกพรุน คะแนน VBQ ให้ค่า predictive value เชิงบวก 32% (95% CI, 28.14%–36.23%) predictive value เชิงลบ 92% (95% CI, 76.02%–98.01%) และความถูกต้อง (accuracy) 47.6% (95% CI, 37.78%–57.59%)

สรุป: คะแนน VBQ เป็นเครื่องมือที่มีประสิทธิภาพและสามารถใช้เป็นการคัดกรองเบื้องต้นสำหรับโรคกระดูกพรุนได้ แต่ไม่สามารถทดแทนการตรวจ DXA ได้ คะแนน VBQ < 3.1 สามารถใช้ตัดโรคกระดูกพรุนออกไปได้ ในขณะที่คะแนน VBQ ≥ 3.2 ควรได้รับการตรวจเพิ่มเติม เช่น การตรวจ DXA ซึ่งถือเป็น gold standard

คำสำคัญ: ความหนาแน่นของกระดูก, คุณภาพกระดูกสันหลัง, การตรวจวัดความหนาแน่นของมวลกระดูก, ภาพถ่ายรังสีของกระดูกสันหลัง, กระดูกสันหลังเสื่อม

Introduction

Osteoporosis is common bone disease, it showed significantly decreases in bone mineral density and micro-architectural deterioration of bone tissue.[1] Osteoporosis is higher risk for lumbar spine degeneration and increases the risk for complications in patients undergoing spine surgery, causing implant failure or pseudarthrosis.[2,3]

Dual Energy X-ray Absorptiometry (DXA) is recommended by The World Health Organization (WHO) as the gold standard method for the assessment of bone mineral density (BMD).[4,5] However, it has some limitation. In severe lumbar degenerative patients, T-score measured by DXA can be overestimated because of osteophyte formation, facet hypertrophy and bone sclerosis, which increase absorption of the x-ray projection path and leading to falsely increase in the BMD.[6,7]

Few studies had shown that magnetic resonance imaging (MRI) may be utilized to measure

bone quality using changes in bone marrow signal observed on T1-weighted MRIs to calculate the Vertebral bone quality (VBQ) score.[8] Bone mineral loss occurs in trabecular bone at mid-vertebral body. Osteoporotic bone tissue that has undergone adipocyte replacement exhibits a prominent signal intensity in trabecular bone on T1-weighted images. This observation provides a theoretical foundation for the use of magnetic resonance imaging (MRI) in the evaluation of bone quality.[8,9,10,11]

Accordingly, the primary outcome of this study is to assess the diagnostic efficacy of VBQ score obtained from MRI for actual BMD in the degenerative lumbar spine and to correlate this measure with DXA-assessed T-scores. The second outcome, to evaluate cut point of the VBQ score to osteoporosis diagnosis.

Materials and Methods

Patient population

This study was approved by the Ethics Committee of the hospital. We retrospectively reviewed patients from medical records and BHIS (Bhumibol Adulyadej Hospital Information System), searching for ICD 10.

- M480: Spinal stenosis
- M530: Spinal instability
- M4799: Spondylosis
- M431: Spondylolisthesis
- M80: Osteoporosis with pathologic fracture
- M819: Osteoporosis, unspecified

From May 2019 to December 2023, total 161 patients who met the inclusion criteria were as follows 1. Age > 18 years old, 2. Diagnosed degenerative spine or osteoporosis, 3. MRI spine T1-weighed and DXA scan at the same time within 3 months before surgery. According to clinical and radiological data, patients were excluded from this study if they met one or more of the following criteria: previous lumbar spine and hip fusion surgery, spinal infection, tumor, and radiation therapy.

After screening out eligible patients, demographic data were collected for each patient, as age, sex, menopause, body mass index (BMI), smoking, diabetic mellitus, hypertension, rheumatoid arthritis, diagnosis, treatment (operative/conservative), medical use (antiresorptive, anabolic therapy).

Imaging

All patients were examined by DXA (Horizon® DXA System, Software version 13.6.1.3) of the lumbar spine and hip to obtain the information, including spine T-score, hip T-score. Based on the World Health Organization (WHO) classification, the diagnostic criteria of osteoporosis was defined as a T-score less than -2.5, osteopenia was defined as T-score between -1 to -2.5 and normal was defined as T score more than -1. In addition, all patients were performed MRI lumbosacral spine (GE Signa HD 1.5T MRI System). All images were transferred to PACs system for viewing and analysis.

VBQ measurements were analyzed using T1-weighted images, mid sagittal view. A round-shaped region of interest (ROI) was measured on the L1-L4 mid vertebral body and L3 CSF SI. (Figure 1) First, the median SI values of L1-4 vertebral body were calculated, and then The L3 CSF SI was divided to

determine the relative VBQ value. Measurements were performed three times by two doctors (author and advisor) were blinded to patient DXA and mean values were calculated.

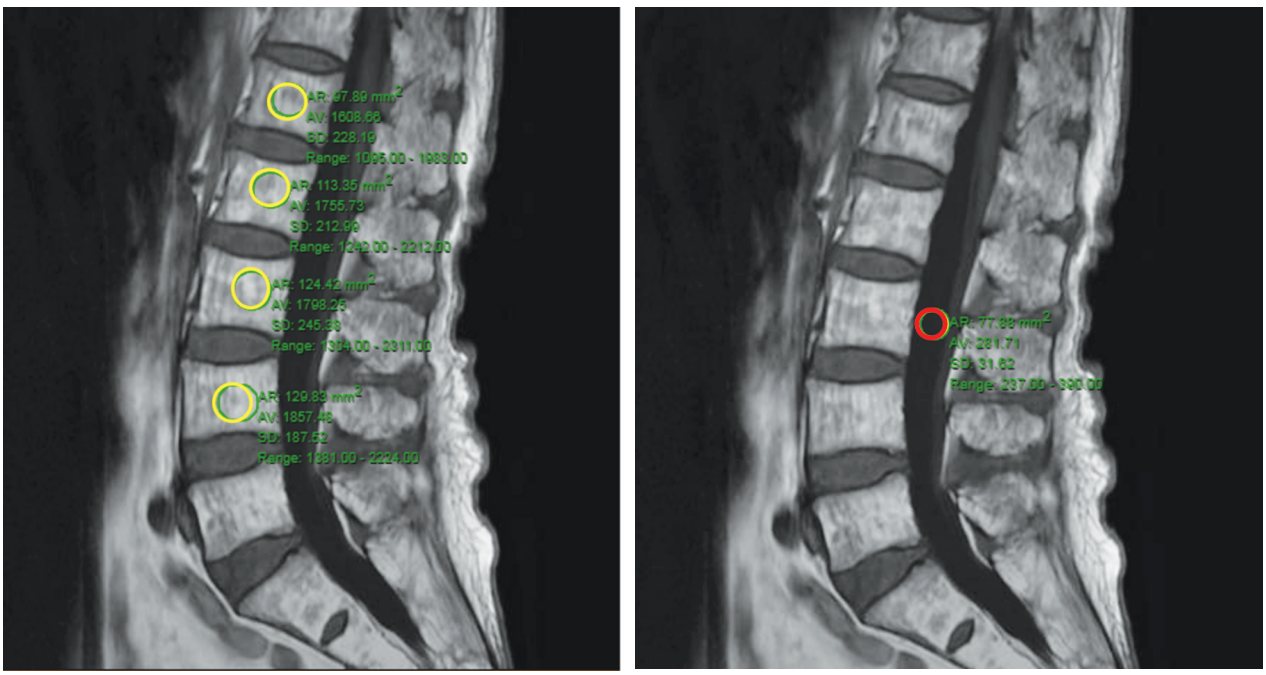

Figure 1 Magnetic resonance imaging (MRI) of lumbosacral spine T1-weight images, Mid-sagittal view, A circular region of interest (ROI) was placed on the L1-L4 mid vertebral body and and L3 CSF SI to evaluate VBQ score.

Statistical analysis

IBM SPSS version 29 was employed for statistical analysis. Continuous data conformed to a normal distribution, characterized by a mean and standard deviation. Categorical data were presented as percentages and were analyzed utilizing the Fisher's exact probability test. The Pearson correlation coefficient was employed to evaluate the correlation between the VBQ score and another variable, spine T-score and hip T-score. The receiver operating characteristic curve (ROC) was used to analyze the differential value of the VBQ score in osteopenia and osteoporosis and calculated their specificity, sensitivity, negative predictive value (NPV) and positive predictive value (PPV) and accuracy for diagnostic tool. The coordinates of the curve were utilized to ascertain the cutoff value for VBQ, thereby enabling the differentiation of patients with osteoporosis and osteopenia.

Results

A total 161 patients were included in this study. The average age was 71.4 ± 10.1 years. There were 122 females (75.8%) and 39 males (24.2%). Two sets of detailed demographic data and measured VBQ and DXA (spine T-score, hip T-score) data were recorded. (Table 1)

Table 1 Demographic data and measured vertebral bone quality (VBQ) and dual-energy X-ray absorptiometry (DXA) data

Parameter	Mean ± SD
Age (years)	71.4 ± 10.1
Sex	
Female	122 (75.8%)
Menopause	113 (70.2%)
BMI (kg/m^2)	24.4 ± 4.7
Smoking	35 (21.7%)
Comorbidities	
Diabetes	33 (20.5%)
Hypertension	66 (41.0%)
Rheumatoid arthritis	34 (21.1%)
Treatment	
Catabolic medication	6 (3.7%)
Anabolic medication	32 (19.9%)
Spine T-score	-0.9 ± 1.7
Hip T-score	-1.7 ± 1.1
VBQ	4.6 ± 1.5

The BMD value correlated inversely with the VBQ score, with a Pearson correlation coefficient > -0.3 (Table 2). The relationship between VBQ score and T-score of spine and hip was visualized by a scatter plot (Figure 2). For the overall correlation (all $P < 0.001$), the VBQ score and spine and hip T-score showed a moderate correlation (r = -0.356 and -0.341).

Analyzing the BMD value and VBQ score using ROC (Figure 3), the area under the curve (AUC) was determined to be 0.652 (95% confidence interval [CI], 0.555-0.750) for osteopenia and 0.674 for osteoporosis (95% CI, 0.558-0.790).

The VBQ score of osteoporosis (Table 3) for positive predictive value (PPV) 32% (95% CI 28.14%-36.23%), negative predictive value (NPV) 92% (95% CI 76.02%-98.01%) and accuracy 47.6% (95% CI 37.78%-57.59%).

According to the control group data, the VBQ thresholds for osteopenia (-1 < T-score < 2.5) and osteoporosis (T-score < 2.5) were calculated and adjusted to one decimal place for the threshold value. (Table 4)

Based on the adjusted threshold criteria of the VBQ score, a score of 2.8-3.1 for osteopenia and score > 3.2 for osteoporosis.

Table 2 Vertebral bone quality (VBQ) score correlated with bone mineral density (BMD) value (r value)

	Correlation
Spine T score	-0.356*
Hip T score	-0.341*

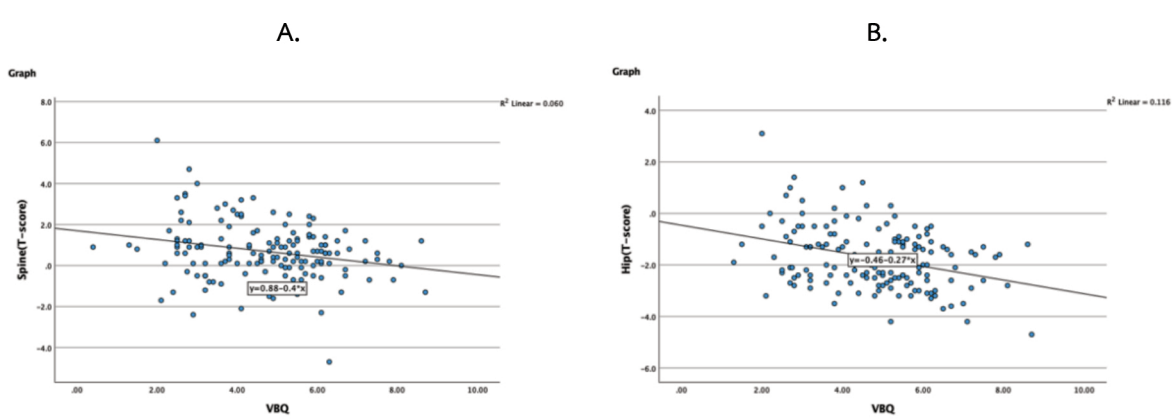

Figure 2 Scatter plots showing correlation between vertebral bone quality (VBQ) scores and bone mineral density (BMD) values (Spine T-score: A, Hip T-score: B)

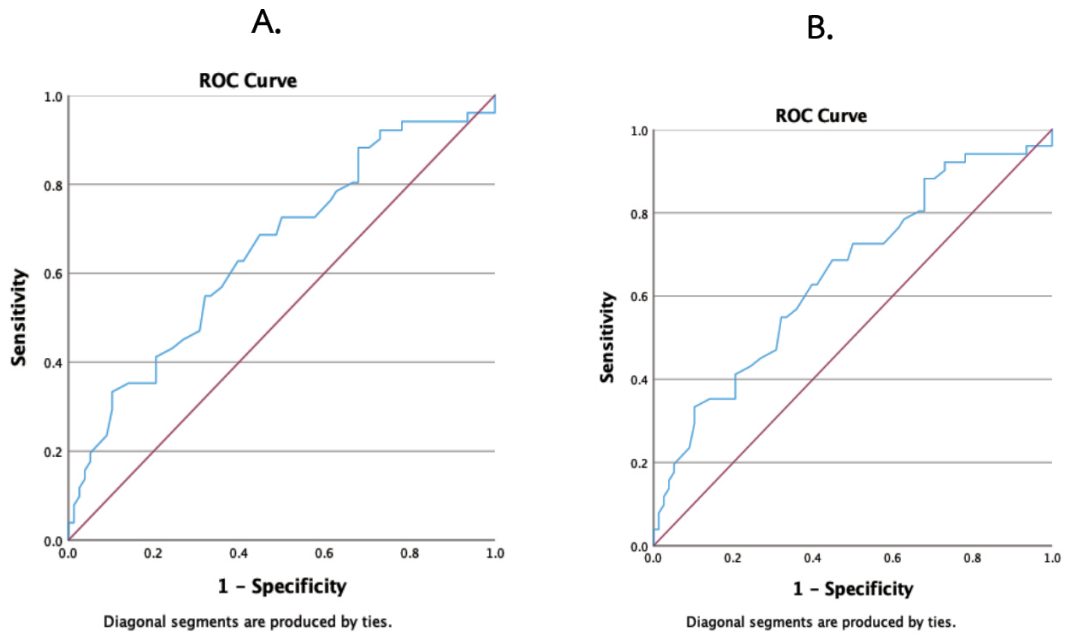

Figure 3 The receiver operating characteristics curve indicates the Vertebral bone quality (VBQ) score as a diagnostic tool for osteopenia (A) and osteoporosis (B), in determined area under curve (AUC)

Table 3 Vertebral bone quality (VBQ) score for diagnosing osteoporosis

Parameter	Value (95% CI)
Positive predictive value (PPV)	32% (28.14%-36.23%)
Negative predictive value (NPV)	92% (76.02%-98.01%)
Accuracy	47.6% (37.78%-57.59%)

Table 4 Cut of vertebral bone quality (VBQ) score was diagnostic of osteoporosis and osteopenia

Criterion	VBQ threshold	Adjustment threshold	Sensitivity%	Specificity%	AUC (95%CI)
Osteopenia	2.72	2.8	94	22	0.652(0.555-0.750)
Osteoporosis	3.15	3.2	92	33	0.674(0.558-0.790)

Discussion

In this study, all patients had routine noninvasive imaging both MRI lumbosacral spine and dual-energy X-ray absorptiometry (DXA). All images in PACs system were used to measure VBQ score, using T1-weighted images, mid-sagittal view. A circular region of interest (ROI) was placed on the L1-L4 mid vertebral body and L3 CSF SI. The ROI on the cancellous portion of the mid-vertebral body, not affected by degenerative changes in either endplate or cortical bone led to more accurate BMD measurement.[8] In the present study, greater emphasis was placed on lumbar bone density, suggesting that VBQ scores may not accurately indicate the reliability of

bone quality. Our analysis was conducted using DXA as a reference standard, thereby eliminating the limitations associated with degenerative changes.

The primary objective of this study was to assess the diagnostic efficacy of VBQ scores in predicting osteoporosis in degenerative spine patients. Correlations between T-score (DXA) and VBQ (MRI lumbosacral spine) was determined also been demonstrated in other studies.[12,13] In this study, the BMD value correlated inversely with the VBQ score, with a Pearson correlation coefficient > −0.3. The VBQ score has good predictive ability for osteopenia (AUC = 0.652 (95% CI, 0.555-0.750)) and osteoporosis (AUC = 0.674(95% CI, 0.558-0.790)) with that of the latter being slightly stronger. The sensitivity was 92%, specificity 22% and accuracy 47.6% (95% CI 37.78%-57.59%). Our results were different from previous studies[14-17] published on the topic have highly variable results, with accuracies in predicting the presence of osteopenia/osteoporosis ranging from 67% to 89%, an overall sensitivity ranging from 58% to 84.7%, and a specificity ranging from 40.6% to 90%. For this study, the heightened sensitivity of the resulting threshold is suitable for high-risk populations characterized by diminished bone quality and impaired ability to discern negative occurrences. Conversely, low specificity may encompass instances of severe osteoporosis.

The adjusted threshold criteria of the VBQ score, score 2.8-3.1 for osteopenia and score > 3.2 for osteoporosis. Our VBQ thresholds were different from other studies,[18] in Mengyang Pu's study showed VBQ scores of 2.81 ± 0.28 (normal BMD), 3.06 ± 0.36 (osteopenia), and 3.43 ± 0.37 (osteoporosis), different results may be due to several factors, such as population size, race, bone density reference standard, and scanner types.

Despite the inferiorities of VBQ measurement, the time and cost involved in obtaining VBQ measurements were greater compared with DXA scan and it can be used as a primary screening tool for osteoporosis, but can not replace DXA scan for definite osteoporosis diagnosis

Limitation

The study has limitations. First, this study is retrospective design, with associated potential for bias. Second, cancellous bone is not homogenous, thus the ROI of only the mid vertebral section might not accurately represent bone quality and measurement is manually selected and prone to subjectivity. Third, this study is single-center study and for measured VBQ score depend on the type of machine, differences in field strength (1.5 vs 3.0 T) MRI spine. Forth, narrow cut of VBQ value for differentiate between osteopenia (2.8-3.1) and osteoporosis (> 3.2). Last, we also obtained VBQ scores with low specificity, there are needed for inclusion and increased populations in the future.

Conclusion

According to our results, VBQ is an effective tool for differentiating patients with degenerative spine. A VBQ score < 3.1 should exclude osteoporosis, whereas a VBQ score ≥ 3.2 suggests the need for further investigation such as DXA (gold standard) for confirm diagnosis.

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