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Visceral Adiposity Index Outperforms Body Mass Index in Predicting Early Cage Subsidence Following Lumbar Interbody Fusion: A Retrospective Cohort Study

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Visceral Adiposity Index Outperforms Body Mass Index in Predicting Early Cage Subsidence Following Lumbar Interbody Fusion: A Retrospective Cohort Study

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Abstract

Background: Conventional anthropometric indices like Body Mass Index (BMI) often fail to accurately capture the metabolic risks affecting bone quality in spinal surgery. This study aimed to investigate the predictive value of the Visceral Adiposity Index (VAI) for early cage subsidence following lumbar interbody fusion (LIF) and to compare its diagnostic accuracy with traditional obesity metrics.

Methods: A retrospective cohort study was conducted on 347 patients who underwent 1- or 2-level LIF. Early cage subsidence was defined as ≥2 mm sinking into the adjacent vertebral endplate. VAI was calculated based on baseline anthropometric and lipid parameters. Multivariate logistic regression models were employed to identify independent risk factors. A restricted cubic spline (RCS) model and receiver operating characteristic (ROC) curves were utilized to evaluate the dose-response relationship and predictive performance.

Results: Early cage subsidence occurred in 83 patients (23.9%). In the fully adjusted multivariate model, elevated VAI (aOR = 1.58, 95% CI: 1.25–2.01, P < 0.001), older age, and lower BMD T-score remained independent predictors, whereas BMI and diabetes lost their statistical significance. RCS analysis revealed a significant non-linear threshold effect (P for non-linearity = 0.012), showing a sharp increase in subsidence risk once VAI exceeded 2.40. ROC analysis demonstrated that VAI (AUC = 0.785, optimal cut-off > 2.85) possessed significantly superior predictive accuracy compared to BMI (AUC = 0.642, P = 0.002) and waist circumference (AUC = 0.685, P = 0.015). Subgroup analyses confirmed the robust predictive value of high VAI across various clinical demographics.

Conclusions: Elevated preoperative VAI is a novel and powerful independent predictor of early cage subsidence after LIF, significantly outperforming BMI. These findings suggest that the deleterious metabolic microenvironment of visceral adiposity, rather than pure mechanical loading, primarily compromises endplate integrity. VAI can serve as an invaluable, cost-effective tool for preoperative risk stratification.

Keywords: Visceral Adiposity Index (VAI); Cage subsidence; Lumbar interbody fusion; Body Mass Index (BMI); Fat-bone crosstalk; Predictive risk factors.

1. Introduction

Lumbar interbody fusion (LIF) has become a standard and highly effective surgical treatment for various degenerative lumbar spine diseases [1, 2]. By inserting an intervertebral cage, LIF restores intervertebral disc height, enlarges the neural foramen, and provides immediate biomechanical stability to facilitate solid bony fusion [3]. However, cage subsidence—defined as the sinking of the cage into the adjacent vertebral endplates—remains a prevalent and challenging postoperative complication [4, 5]. Early cage subsidence, typically occurring within the first few months after surgery, is particularly detrimental. It compromises the surgical goals by leading to loss of sagittal alignment, recurrent foraminal stenosis, pseudoarthrosis, and subsequent

chronic pain, and may necessitate complex revision surgery [6, 7]. Therefore, identifying modifiable preoperative risk factors for early cage subsidence is of paramount clinical importance for optimal patient selection and surgical planning.

The etiology of cage subsidence is multifactorial, involving a complex interplay of surgical technique, implant characteristics, and patient-specific anatomical and systemic conditions [6–8]. Among patient-related factors, advanced age and compromised bone quality (e.g., osteopenia or osteoporosis) are well-established drivers of endplate failure [9–11]. Local endplate integrity and fracture susceptibility also influence the risk of mechanical failure [12]. Recently, the impact of obesity and metabolic disturbances on spinal surgery outcomes has garnered increasing attention [13–15]. Traditionally, Body Mass Index (BMI) has been the most widely adopted metric for defining obesity. However, BMI cannot differentiate fat from muscle mass or distinguish subcutaneous from visceral fat, limitations that are increasingly relevant when interpreting obesity-related skeletal risk [16–18]. Because visceral adipose tissue is metabolically active and linked to adverse cardiometabolic profiles, relying solely on BMI may fail to capture the metabolic and structural risks posed by adiposity [19–21].

To overcome the diagnostic limitations of traditional anthropometric measurements, the Visceral Adiposity Index (VAI) is used as a sex-specific empirical index that combines BMI and waist circumference with triglyceride and high-density lipoprotein cholesterol levels [19, 20]. Recent population studies have linked VAI to insulin resistance and cardiometabolic multimorbidity [20, 21]. VAI has also shown nonlinear or saturation-type associations with bone mineral density, supporting its potential relevance to skeletal health [17, 22]. Importantly, emerging evidence highlights profound fat–bone crosstalk [23, 24]. Obesity-related inflammatory and adipokine signaling can promote osteoclast activity and impair osteoblast function, thereby disrupting bone remodeling [24, 25]. Bone marrow adipose tissue may further alter the osteogenic–adipogenic balance and compromise trabecular microarchitecture [23, 26]. Despite this biological plausibility, the clinical utility of VAI for predicting

orthopedic complications—specifically interbody cage subsidence following spinal fusion—remains largely unexplored.

To address this knowledge gap, we conducted this retrospective cohort study to investigate the association between preoperative VAI and the risk of early cage subsidence in patients undergoing LIF. Furthermore, we sought to explore the potential dose-response relationship using a restricted cubic spline (RCS) model, and to evaluate whether VAI provides superior predictive accuracy compared to traditional indices such as BMI and waist circumference. We hypothesized that an elevated VAI is an independent risk factor for early cage subsidence and serves as a more precise, comprehensive predictive tool than conventional obesity metrics.

2. Methods

2.1 Study Design and Patient Population

This retrospective cohort study was conducted at the 960th Hospital of the PLA, Jinan, China, between 2021 and 2024. The study protocol was approved by the Ethics Committee of the 960th Hospital of the PLA (approval No. 2026 Research Ethics Review No. 140). The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The requirement for informed consent was waived by the Ethics Committee because of the retrospective nature of the study and the use of de-identified clinical data.

Patients who underwent lumbar interbody fusion (LIF) surgery with cage insertion were reviewed for eligibility. The inclusion criteria were as follows: (1) patients aged 18 years or older; (2) diagnosis of degenerative lumbar spine diseases (e.g., lumbar spinal stenosis, lumbar disc herniation, or degenerative spondylolisthesis) requiring 1- or 2-level LIF surgery; (3) availability of complete preoperative anthropometric data (height, weight, and waist circumference) and fasting lipid profiles within one week prior to surgery; (4) availability of preoperative Dual-energy X-ray absorptiometry (DEXA) scans for bone mineral density (BMD) assessment;

and (5) adequate clinical and radiographic follow-up of at least 6 months postoperatively.

The exclusion criteria included: (1) history of previous lumbar spine surgery; (2) spinal tumor, trauma, infection, or severe spinal deformity; (3) severe systemic diseases such as end-stage renal disease, liver failure, or untreated severe thyroid disorders that heavily affect lipid and bone metabolism; (4) chronic use of medications significantly affecting bone or lipid metabolism (e.g., long-term systemic corticosteroids); and (5) incomplete medical records or unreadable radiographic images. Following these criteria, a total of 347 patients were finally included in the analysis.

2.2 Data Collection and Variable Definitions

Baseline demographic and clinical data were extracted from the electronic medical record system, including age, sex, presence of diabetes mellitus, surgical segments (single- or double-level), and cage height. Anthropometric measurements, including weight, height, and waist circumference (WC), were recorded by trained nursing staff on the day of admission. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Fasting venous blood samples were drawn in the early morning to measure triglycerides (TG, mmol/L) and high-density lipoprotein cholesterol (HDL-C, mmol/L). Preoperative BMD of the lumbar spine and proximal femur was measured using a DEXA scanner , and the lowest T-score was recorded.

The primary exposure variable, Visceral Adiposity Index (VAI), was calculated using sex-specific formulas that integrate anthropometric (BMI and WC) and metabolic (TG and HDL-C) parameters [17, 19, 20]:

$$\textbf{Males: } VAI = \left(\frac{WC}{39.68+(1.88\times BMI)}\right) \times \left(\frac{TG}{1.03}\right) \times \left(\frac{1.31}{HDL-C}\right)$$

Females: $VAI = \left(\frac{WC}{36.58+(1.89\times BMI)}\right) \times \left(\frac{TG}{0.81}\right) \times \left(\frac{1.52}{HDL-C}\right)$

Note: In the formulas, WC is expressed in cm, and TG and HDL-C are expressed in mmol/L.

2.3 Radiographic Evaluation and Outcome Measure

Standardized weight-bearing anteroposterior and lateral radiographs, as well as computed tomography (CT) scans, were performed preoperatively, postoperatively, and at each follow-up visit. The primary outcome was early cage subsidence, radiographically defined as sinking of the cage into the adjacent superior or inferior vertebral endplate by ≥2 mm within 6 months postoperatively, consistent with contemporary subsidence definitions [4, 5]. Radiographic measurements were independently assessed by two experienced spine surgeons blinded to the patients' clinical and metabolic data. Any discrepancies were resolved through discussion with a third senior surgeon.

2.4 Statistical Analysis

All statistical analyses were performed using R software (version 4.2.3, R Foundation for Statistical Computing, Vienna, Austria). A two-tailed P value < 0.05 was considered statistically significant. Continuous variables with a normal distribution were presented as mean ± standard deviation (SD) and compared using the independent Student’s t-test. Categorical variables were expressed as frequencies (percentages) and compared using the Pearson chi-square test or Fisher’s exact test, as appropriate. To identify independent risk factors for early cage subsidence, variables with P < 0.10 in univariate logistic regression, together with clinically relevant variables, were incorporated into multivariate logistic regression models. Three progressive models were constructed: Model 1 was adjusted for age and sex; Model 2 was further adjusted for BMI, BMD T-score, and diabetes mellitus; and Model 3 additionally included surgical segments and cage height. Results were presented as odds ratios (ORs) and

adjusted odds ratios (aORs) with 95% confidence intervals (CIs). A restricted cubic spline (RCS) function was embedded in the fully adjusted logistic model to flexibly evaluate a potential nonlinear relationship between continuous VAI and cage subsidence risk [27]. The median VAI value (2.40) was used as the reference point (OR = 1). Predictive performance of VAI, BMI, and WC was assessed using receiver operating characteristic (ROC) curves, with area under the curve (AUC), the DeLong test for paired AUC comparisons, and the Youden index for selecting the optimal cut-off [28]. Finally, subgroup analyses stratified by sex, age, and BMD status were conducted, with interaction terms used to evaluate the stability of VAI across subgroups; results were presented as a forest plot.

3. Results

3.1 Baseline demographic and clinical characteristics

Following the inclusion and exclusion criteria, a total of 347 patients were eventually enrolled in this study （**Figure 1** ）. During the follow-up period, early cage subsidence occurred in 83 patients, yielding an overall incidence rate of 23.9%. The baseline demographic, clinical, and surgical characteristics of the study population are summarized in **Table 1**.

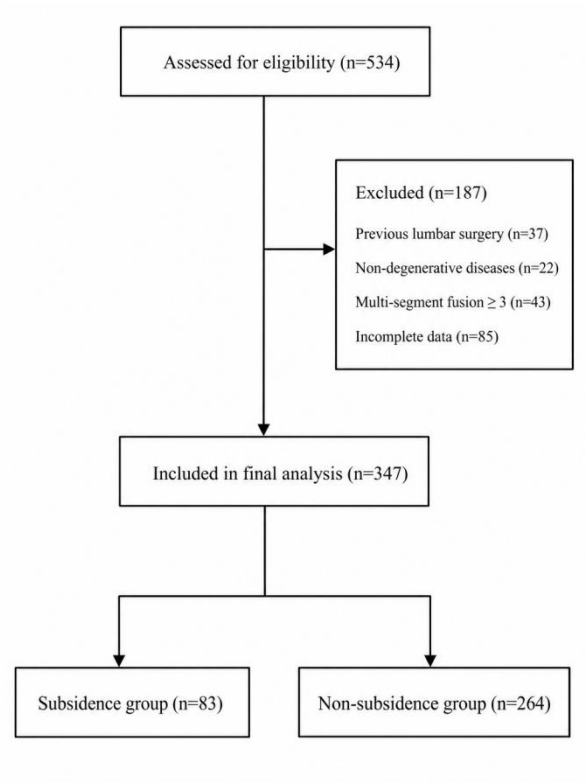


Figure 1. Flowchart of patient selection and study design.

Table 1. Baseline demographic, clinical, and surgical characteristics of the study population

Variables	Total (N = 347)	Non-subsidence (n = 264)	Subsidence (n = 83)	P value
Age (years)	59.5 ± 8.5	58.2 ± 8.5	63.5 ± 7.2	< 0.001
Sex (Female)	185 (53.6)	138 (52.5)	47 (57.3)	0.445
BMI (kg/m²)	25.5 ± 3.4	25.1 ± 3.2	26.8 ± 3.5	0.001
Waist circumference (cm)	87.8 ± 9.3	86.3 ± 9.1	92.5 ± 8.4	< 0.001
VAI	2.43 ± 1.05	2.12 ± 0.85	3.45 ± 1.20	< 0.001
Triglycerides (mmol/L)	1.68 ± 0.85	1.62 ± 0.80	1.88 ± 0.95	0.012
HDL-C (mmol/L)	1.22 ± 0.35	1.25 ± 0.36	1.12 ± 0.30	0.003
Diabetes mellitus	76 (22.0)	49 (18.6)	27 (32.9)	0.008
BMD T-score	-1.3 ± 1.0	-1.2 ± 1.0	-1.8 ± 0.9	< 0.001
Surgical segments				0.185
Single-level	275 (79.7)	213 (81.0)	62 (75.6)	
Double-level	70 (20.3)	50 (19.0)	20 (24.4)	
Cage height (mm)	11.2 ± 1.4	11.1 ± 1.3	11.4 ± 1.5	0.082

Note: Data are expressed as mean ± standard deviation or number (percentage). BMI, body mass index; VAI, visceral adiposity index; HDL-C, high-density lipoprotein cholesterol; BMD, bone mineral density. Bold values indicate statistical significance.

Compared to the non-subsidence group, patients in the subsidence group were significantly older (63.5 ± 7.2 vs. 58.2 ± 8.5 years, $P < 0.001$) and had a lower bone mineral density (BMD) T-score (-1.8 ± 0.9 vs. -1.2 ± 1.0, $P < 0.001$). Regarding adiposity and metabolic indicators, the subsidence group exhibited significantly higher BMI, waist circumference, and visceral adiposity index (VAI) (all $P < 0.001$), as well as elevated triglycerides ($P = 0.012$) and lower high-density lipoprotein cholesterol (HDL-C) levels ($P = 0.003$). The prevalence of diabetes mellitus was also higher in the subsidence group (32.9% vs. 18.6%, $P = 0.008$). Notably, the distribution of preoperative adiposity indices demonstrated that VAI provided the most distinct visual separation between the two groups compared to BMI and waist circumference （**Figure 2**） . No significant differences were observed between the two groups in terms of sex, surgical segments, or cage height (all $P > 0.05$).

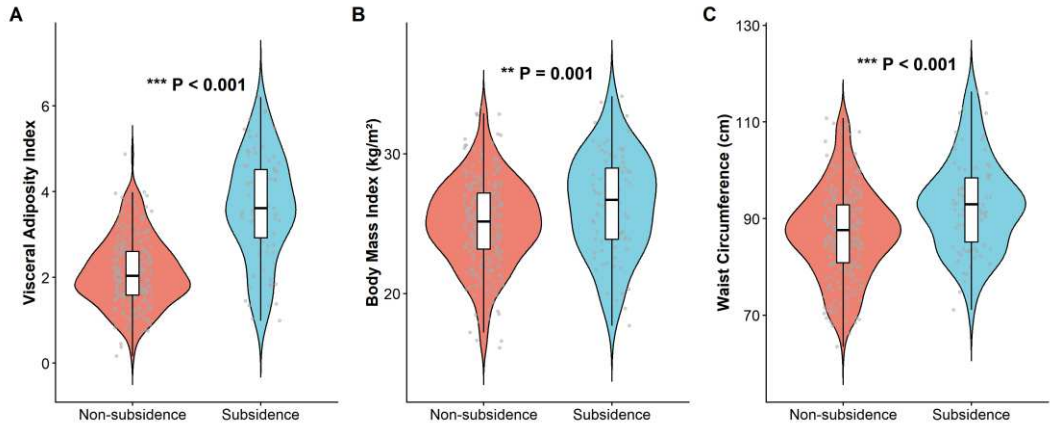


Figure 2. Distribution of preoperative adiposity indices between the subsidence and non-subsidence groups. (A) Visceral Adiposity Index (VAI); (B) Body Mass Index (BMI); (C) Waist circumference. VAI demonstrated the most distinct separation between the two groups. **$P < 0.001$.

3.2 Independent risk factors for early cage subsidence

Univariate and multivariate logistic regression analyses were conducted to identify the independent risk factors for early cage subsidence (**Table 2**). In the univariate analysis, increased VAI, older age, higher BMI, lower BMD T-score, and

the presence of diabetes mellitus were significantly associated with an increased risk of subsidence.

To rigorously evaluate the independent effect of VAI, three multivariate models were constructed. After adjusting for age and sex (Model 1), and further adjusting for BMI, BMD T-score, and diabetes (Model 2), higher VAI remained a significant risk factor. In the fully adjusted model (Model 3), which additionally incorporated surgical segments and cage height, VAI was confirmed as an independent predictor of early cage subsidence (adjusted odds ratio [aOR] = 1.58 per 1-unit increase, 95% CI: 1.25–2.01, $P < 0.001$). Furthermore, older age (aOR = 1.08, $P = 0.004$) and a lower BMD T-score (aOR = 0.65, $P = 0.001$) also remained significant independent predictors in Model 3, whereas BMI and diabetes lost their statistical significance.

Table 2. Univariate and multivariate logistic regression analyses of risk factors for early cage subsidence

Variables	Univariate Analysis		Model 1		Model 2		Model 3	
OR (95% CI)	P value	aOR (95% CI)	P value	aOR (95% CI)	P value	aOR (95% CI)	P value	
VAI (per 1 unit)	1.95 (1.62–2.35)	<0.001	1.88 (1.55–2.28)	<0.001	1.65 (1.31–2.08)	<0.001	1.58 (1.25–2.01)	<0.001
Age (years)	1.10 (1.05–1.15)	<0.001	1.11 (1.06–1.16)	<0.001	1.08 (1.03–1.14)	0.002	1.08 (1.02–1.14)	0.004
Sex (Female)	1.21 (0.75–1.98)	0.445	1.15 (0.68–1.92)	0.582	–	–	–	–
BMI (kg/m²)	1.16 (1.06–1.28)	0.001	–	–	1.08 (0.98–1.20)	0.125	1.06 (0.95–1.18)	0.285
BMD T-score	0.55 (0.43–0.70)	<0.001	–	–	0.62 (0.48–0.81)	<0.001	0.65 (0.50–0.84)	0.001
Diabetes mellitus	2.15 (1.25–3.70)	0.008	–	–	1.55 (0.85–2.82)	0.152	1.48 (0.80–2.75)	0.21

Note: Model 1 was adjusted for age and sex. Model 2 was adjusted for variables in Model 1 plus BMI, BMD T-score, and diabetes mellitus. Model 3 was fully adjusted for variables in Model 2 plus surgical segments and cage height. OR, odds ratio; aOR, adjusted odds ratio; CI, confidence interval.

3.3 Dose-response relationship between VAI and cage subsidence

To further visualize the dynamic association between continuous VAI and the risk of early cage subsidence, a restricted cubic spline (RCS) curve based on the fully adjusted model was plotted **(Figure 3)** . The median VAI value (2.40) was set as the reference point (OR = 1). The RCS analysis revealed a significant non-linear threshold effect (*P* for overall association < 0.001; *P* for non-linearity = 0.012). Specifically, when VAI was relatively low, the risk curve remained flat and stable; however, once VAI surpassed the threshold (approximately 2.40–2.85), the risk of cage subsidence increased sharply in a dose-dependent manner.

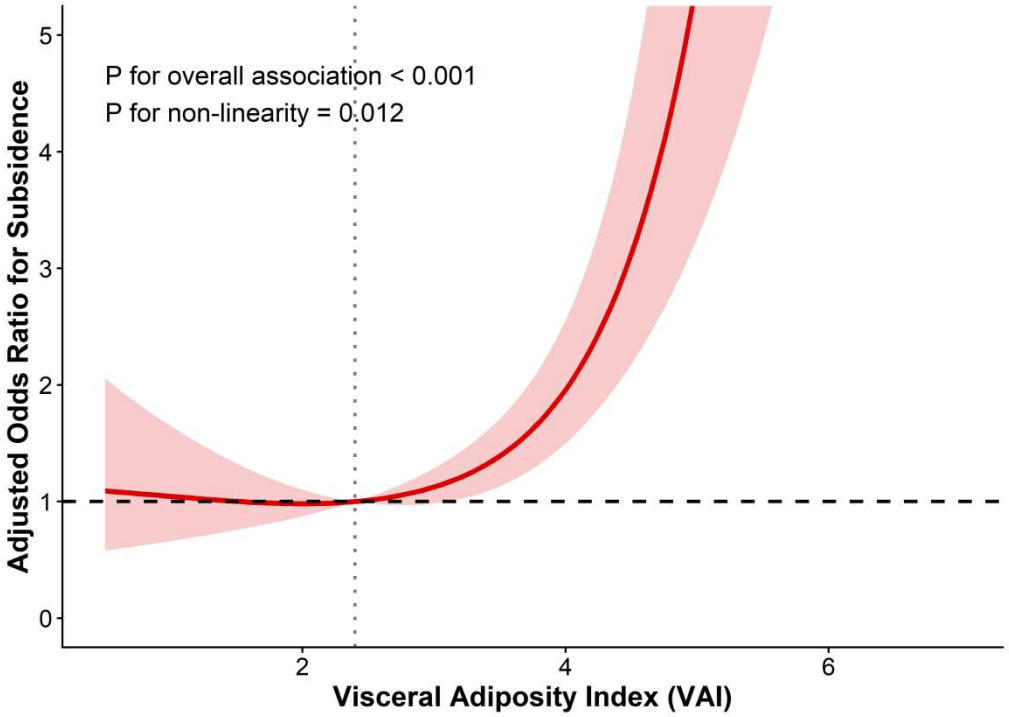


Figure 3. Dose-response relationship between VAI and the risk of early cage subsidence using a restricted cubic spline (RCS) model. The solid red line represents the adjusted odds ratio (OR), and the shaded area indicates the 95% confidence intervals. The reference point (OR = 1) was set at the median VAI value (2.40). The curve shows a non-linear threshold effect (*P* for overall association < 0.001; *P* for non-linearity = 0.012).

3.4 Predictive performance of adiposity indices

Receiver operating characteristic (ROC) curves were generated to compare the diagnostic value of VAI, BMI, and waist circumference for predicting early cage subsidence (**Table 3** and **Figure 4**). VAI demonstrated the highest predictive accuracy, with an area under the curve (AUC) of 0.785 (95% CI: 0.732–0.838). The optimal cut-off value for VAI was calculated to be > 2.85, yielding a sensitivity of 72.5% and a specificity of 76.8%. In contrast, the predictive performances of traditional obesity indices were inferior (BMI: AUC = 0.642; Waist circumference: AUC = 0.685). The DeLong test confirmed that the AUC of VAI was significantly superior to that of BMI ($P = 0.002$) and waist circumference ($P = 0.015$).

Table 3. Predictive performance of VAI, BMI, and waist circumference for early cage subsidence

Indicators	AUC (95% CI)	Cut-off	Sensitivity (%)	Specificity (%)	P value
VAI	0.785 (0.732–0.838)	> 2.85	72.5	76.8	Reference
BMI	0.642 (0.575–0.709)	> 26.5	60.2	65.5	0.002
Waist circumference	0.685 (0.620–0.750)	> 90.5	65.8	68.2	0.015

*Note: AUC, area under the receiver operating characteristic curve; CI, confidence interval. *P values were calculated using the DeLong test to compare the AUC of BMI and waist circumference with that of VAI.*

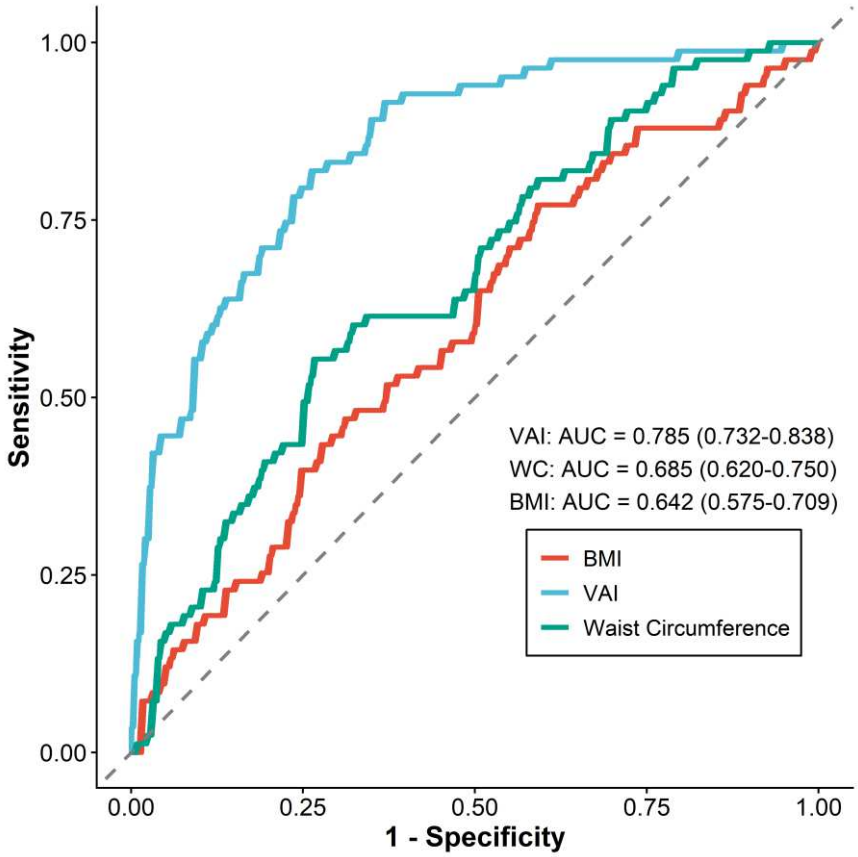


Figure 4. Receiver operating characteristic (ROC) curves of VAI, BMI, and waist circumference for predicting early cage subsidence. VAI (red line) exhibited the highest predictive performance (AUC = 0.785) compared to BMI (AUC = 0.642) and waist circumference (AUC = 0.685).

3.5 Subgroup analyses

Based on the optimal cut-off value from the ROC analysis, patients were dichotomized into a high VAI group (> 2.85) and a low VAI group (≤ 2.85). A forest plot **(Figure 5)** was generated to evaluate whether the association between high VAI and early cage subsidence remained consistent across different clinical subgroups. The results demonstrated that high VAI consistently increased the risk of subsidence regardless of sex, age (< 60 vs. ≥ 60 years), or bone density status (Normal vs. Osteopenia/Osteoporosis). Interaction tests revealed that none of these stratification variables significantly modified the effect of high VAI on subsidence risk (all *P* for interaction > 0.05), highlighting the robustness and broad applicability of VAI as a predictive marker.

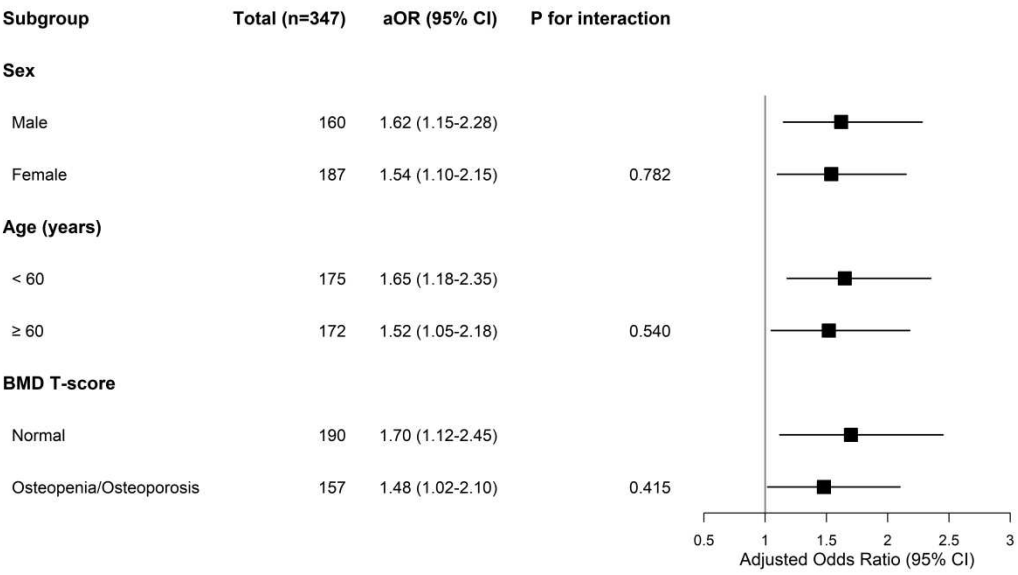


Figure 5. Forest plot showing subgroup analyses for the association between high VAI (> 2.85) and the risk of cage subsidence. The independent predictive value of high VAI remained stable across different demographic and clinical subgroups (all *P* for interaction > 0.05).

4. Discussion

To the best of our knowledge, this is the first study to comprehensively evaluate the predictive value of the Visceral Adiposity Index (VAI) for early cage subsidence following lumbar interbody fusion (LIF). In this retrospective cohort of 347 patients, we observed an overall early cage subsidence incidence of 23.9%. The most salient finding of our study is that an elevated preoperative VAI is a powerful and independent risk factor for early cage subsidence. Furthermore, we established a non-linear, dose-response relationship between VAI and subsidence risk, identifying a critical threshold. Compared to traditional anthropometric measures like BMI and waist circumference, VAI demonstrated significantly superior predictive accuracy, and its prognostic value remained robust across various clinical subgroups.

The impact of obesity on complications following spinal surgery has long been debated [13–15]. Traditionally, high BMI was thought to increase implant-related failure mainly through greater mechanical loading [13, 14]. However, contemporary

evidence emphasizes that BMI alone does not capture adipose distribution, metabolic dysfunction, or bone quality [16–18]. Our findings provide a possible explanation for this limitation. In univariate analysis, BMI was associated with subsidence; after adjustment for metabolic factors, bone density, and surgical parameters in Model 3, BMI lost statistical significance whereas VAI remained an independent predictor. This pattern suggests that the metabolic milieu associated with visceral adiposity, rather than absolute body mass alone, may contribute to cage subsidence. The DeLong test further showed that VAI (AUC = 0.785) had greater diagnostic accuracy than BMI (AUC = 0.642), highlighting the limitations of relying solely on BMI for preoperative risk stratification.

The biological mechanisms underlying the association between high VAI and early cage subsidence may involve fat–bone crosstalk [23, 24]. VAI is a surrogate marker of visceral adiposity and insulin resistance [19, 20]. Unlike subcutaneous fat, visceral adipose tissue functions as an active endocrine organ, and obesity-related adipokine and inflammatory signaling can disturb bone remodeling [24, 25]. These pathways may increase osteoclastogenesis and bone resorption while suppressing osteoblast differentiation [24, 25]. In parallel, marrow adiposity and altered lipid handling may shift mesenchymal differentiation away from osteogenesis, compromising trabecular microarchitecture beneath the vertebral endplates [23, 26]. Consequently, even when systemic BMD appears acceptable, local bone quality may remain vulnerable to biomechanical stress from an interbody cage.

A major strength of the present study is the utilization of a restricted cubic spline (RCS) model to visually and statistically quantify the continuous relationship between VAI and subsidence risk. Interestingly, we identified a non-linear threshold effect. When VAI was relatively low, the risk curve remained flat, suggesting that baseline fat metabolism does not compromise endplate integrity. However, once the VAI exceeded the threshold (approximately 2.40–2.85), the risk of cage subsidence

escalated sharply in a dose-dependent manner. This aligns perfectly with our ROC analysis, which determined an optimal clinical cut-off value of 2.85.

Clinically, these findings may help spine surgeons refine preoperative risk assessment. VAI can be calculated from routinely available BMI, waist circumference, fasting triglyceride, and HDL-C values without specialized imaging [19, 20]. For patients with VAI > 2.85, operative planning should prioritize factors consistently associated with subsidence, including cage dimensions, construct characteristics, and underlying bone quality [29, 30]. Meticulous endplate preparation and avoidance of intraoperative endplate injury are also important [31, 32]. Posterior instrumentation can alter load distribution across the cage–endplate interface and may be considered when biomechanically appropriate [33]. Cage materials and designs, including expandable devices, continue to evolve, but comparative evidence remains mixed and device selection should be individualized [34–36]. Instrumented constructs may provide advantages over stand-alone lateral fusion in selected patients [37]. Metabolic optimization and weight management before elective fusion may also be reasonable; however, although bariatric surgery before spine surgery has been associated with fewer postoperative complications, direct evidence for preventing cage subsidence remains limited [38].

Despite these encouraging findings, several limitations must be acknowledged. First, because of the retrospective design, selection and information biases cannot be completely excluded. Second, this was a single-center study with a moderate sample size; large multicenter prospective studies are needed for external validation. Third, although VAI is a validated surrogate of visceral adiposity, direct volumetric assessment of intra-abdominal and marrow fat by CT or MRI was not performed [18, 26]. Finally, inflammatory cytokines (e.g., IL-6 and TNF-α) and bone turnover markers were not measured, so the proposed mechanisms remain literature-based hypotheses rather than directly observed mediators.

5. Conclusions

In conclusion, an elevated preoperative Visceral Adiposity Index (VAI) is an independent risk factor for early cage subsidence following lumbar interbody fusion. VAI demonstrates a non-linear threshold effect and exhibits significantly superior predictive performance compared to traditional obesity metrics such as BMI. As a cost-effective and easily accessible metabolic parameter, VAI > 2.85 can serve as a valuable tool for spine surgeons in preoperative risk stratification, patient counseling, and the formulation of individualized surgical strategies to optimize fusion outcomes.

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Ethics Committee of the 960th Hospital of the PLA (approval No. 2026 Research Ethics Review No. 140). The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The requirement for informed consent was waived by the Ethics Committee because of the retrospective nature of the study and the use of de-identified clinical data.

Consent for publication

Not Applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to patient privacy and ethical considerations but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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This research received no external funding.

Authors' contributions

Zhaohu Mao and Changsheng Han were involved in study design, data collection, imaging measurements, data analysis, manuscript drafting, and manuscript review. Shuai Wang participated in data collection, imaging measurements, and manuscript review. Jianhua Li contributed to statistical analysis and manuscript review. Qunqun Shan contributed to study design, study supervision, and manuscript review. All authors read and approved the final manuscript.

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