SPECT/CT Diagnostic Performance After Fusion: Does Patient Sex Matter?

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INTRODUCTION: Low back pain (LBP) is the leading cause of years lived with disability worldwide and is projected to affect 800 million people by 2050 [1-3]. While many cases improve with conservative treatments like physical therapy or pain management, persistent or severe cases may require spinal fusion (> 400,000 fusions/year in the US) [4-6]. Pseudarthrosis— the failure of bony fusion across the intended spinal levels at a minimum of 6 months post-op— remains a costly and disabling complication of spinal fusion, with rates ranging from 0% to over 60% depending on surgical approach, instrumentation, and number of levels fused [7-10]. Diagnosing pseudarthrosis is challenging due to its vague or nonspecific presentation and the complex overlap with adjacent segment disease, infection, or other sources of axial pain [11, 12] . The standard diagnostic work-up begins with plain radiographs followed by advanced imaging such as CT or MRI [7, 12, 13]. The primary treatment for pseudarthrosis is revision surgery, which also serves as the gold standard for its diagnosis if exploration is done concurrently [12]. The outcomes of revision procedures are mixed, with Carpenter et al. (1996) reporting only 26% of patients undergoing revision achieve good or excellent clinical results, even when imaging confirms solid fusion [14]. Well-established differences in bone structure and healing exist between men and women, which may influence both the development and detection of pseudarthrosis [22]. SPECT/CT has emerged as an adjunct imaging modality that frequently outperforms conventional imaging for detecting pseudarthrosis, though its diagnostic accuracy varies substantially between studies and patient subgroups [12, 15-21]. SPECT/CT, as a functional imaging technique, may be more sensitive to these sex-based differences, contributing to observed variability in its diagnostic performance across subgroups. The goal of this study is to compare the diagnostic performance of SPECT/CT in detecting pseudarthrosis after spinal fusion between male and female patients.

METHODS: We conducted a retrospective cohort study of 54 adult patients (27 males, 27 females) who underwent spinal fusion between 2012 and 2022 with subsequent SPECT/CT imaging at our level 1 trauma center with approval under IRB-23-2104. Demographic and clinical characteristics were compared by sex using appropriate statistical tests: normality was assessed with the Shapiro–Wilk test and equality of variance with Levene's test; two-sided t-tests or Wilcoxon rank-sum tests were used for continuous variables as appropriate, and Fisher's exact test for categorical variables. Diagnostic accuracy of SPECT/CT for detecting pseudarthrosis (Table 2) was assessed on a per-level basis (n = 222 levels), using surgical exploration as the reference standard. Sensitivity, specificity, positive and negative predictive values, accuracy, and diagnostic odds ratios were calculated separately for males and females. Differences in diagnostic performance by sex were compared using Fisher's exact test or a z-test for diagnostic odds ratios. Logistic regression was used to adjust for potential confounders. Statistical significance was defined as two-sided $p < 0.05$. All analyses were performed in RStudio (V2025.05.1+513).

RESULTS: A total of 54 patients (27 males, 27 females) contributed 222 operative levels for analysis. Female patients were significantly younger than males at time of SPECT/CT (mean ± standard deviation (SD): 65.7 ± 8.8 years vs. 71.2 ± 9.8 years, p = 0.04); no other demographic differences between sexes were significant (Table 1). For the detection of pseudarthrosis, SPECT/CT demonstrated significantly higher sensitivity in females than in males (0.96 vs. 0.55, $p < 0.001$), as well as higher negative predictive value (0.95 vs. 0.52, $p < 0.001$), accuracy (0.87 vs. 0.63, $p < 0.001$), and diagnostic odds ratio (82.8 vs. 3.7, $p < 0.001$) (Table 2). Specificity and positive predictive value did not differ significantly by sex. In multivariable logistic regression among SPECT-negative levels, both male sex (OR = 0.17, 95% CI 0.03–0.85, p = 0.04) and older age at SPECT/CT (OR = 0.92 per year, 95% CI 0.87–0.98, p = 0.01) were independently associated with lower odds of a true negative result, after adjusting for BMI, time from fusion, number of fusion levels, and ASA status. The model demonstrated excellent discrimination (AUC = 0.89).

DISCUSSION: This study demonstrates that SPECT/CT has strong diagnostic performance when detecting pseudarthrosis after spinal fusion but differs substantially by sex and age. The superior sensitivity, NPV, and accuracy of SPECT/CT in women may be explained by differences in postmenopausal bone metabolism. In our cohort, the mean female age was 65 years, suggesting most were postmenopausal and therefore exhibited lower baseline osteoblastic activity. We suspect that this reduces diffuse tracer uptake, thereby enhancing the conspicuity of focal uptake at pseudarthrosis sites, improving diagnostic performance. Multivariable analysis confirmed that male sex was associated with approximately 80% lower odds of a true negative result, and increasing age further reduced diagnostic accuracy. These findings indicate that SPECT/CT is most reliable for ruling out pseudarthrosis in female patients, whereas negative results in older male patients warrant further assessment. Despite its retrospective, single-center design and modest sample (54 patients), we minimized bias with predefined inclusion criteria, a surgical gold standard, and covariate-adjusted models, while acknowledging residual per-level clustering by incorporating level count. SPECT/CT is a useful adjunct for diagnosing pseudarthrosis after spinal fusion, but its negative predictive value and accuracy are significantly lower in male and older patients. Clinicians should consider these factors when ordering and interpreting SPECT/CT results, and further studies are needed to elucidate the mechanisms underlying this diagnostic variability.

SIGNIFICANCE/CLINICAL RELEVANCE: This study demonstrates that SPECT/CT is a highly reliable tool for ruling out pseudarthrosis after spinal fusion in female patients, supporting its targeted use to guide confident clinical decision-making and improve patient outcomes.

IMAGES AND TABLES:

Table 1: Baseline characteristics of male and female patients undergoing spinal fusion with SPECT/CT.

Characteristic	Male (n = 27)	Female (n = 27)	p-value
Age ± SD (years)	**71.16 ± 9.77**	**65.68 ± 8.84**	**0.035**
BMI ± SD	28.6 ± 5.18	31.35 ± 5.83	0.084
Fusion Levels ± SD	1.81 ± 1.1	2.81 ± 2.7	0.158
Spine Region, n (%)	Cervical: 18.5% Thoracic: 3.7% Lumbar: 77.8%	Cervical: 14.8% Thoracic: 7.4% Lumbar: 77.8%	1.00
ASA <3, n (%)	33.3%	51.9%	0.271

Table 2: Diagnostic performance of SPECT/CT for pseudarthrosis by sex.

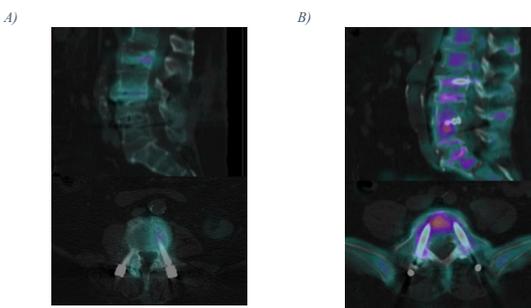| Metrics	Male	Female	p-value
Sensitivity	**0.55**	**0.96**	**<0.001**
Specificity	0.75	0.78	0.80
PPV	0.77	0.82	0.61
NPV	**0.52**	**0.95**	**<0.001**
Accuracy	**0.63**	**0.87**	**<0.001**
DOR	**3.68**	**82.80**	**<0.001**

A) B)

Figure 1: SPECT/CT for pseudarthrosis assessment. A) True negative: SPECT/CT correctly identifies solid fusion confirmed at surgical exploration. B) False negative: SPECT/CT suggests fusion, but pseudarthrosis was confirmed intraoperatively.

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