Original Article

Cervical paraspinal muscle fatty degeneration and postoperative kyphosis after cervical laminoplasty

ABSTRACT

Background: Sarcopenia, a manifestation of frailty characterized by muscle loss, is associated with adverse postoperative events in spinal patients. Its role in postlaminoplasty kyphotic deformities (PKDs) remains unknown.

Objective: This study evaluates the relationship between paraspinal muscle sarcopenia and PKD using qualitative and quantitative methods.

Materials and Methods: A retrospective review was conducted on cervical myelopathy patients treated with laminoplasty between January 2019 and January 2022 at a tertiary care center. Inclusion criteria included pre- and 1-year postoperative X-rays and magnetic resonance imaging within 6 months presurgery. PKD was defined as loss of cervical lordosis greater than 10 based on the C2-7 Cobb angle. Fatty infiltration was evaluated using Goutallier classification and voxel quantification.

Results: Among 44 patients, 4 developed PKD. Qualitatively, 32 patients were classified as Goutallier 0–1.5, 6 were Goutallier 1.5–2.5, and 6 Goutallier 2.5–4. There is a significant association between the Goutallier grade and PKD occurrence after 1 year ($P = 0.00085$). Quantitatively, the average fatty infiltration percentage for the kyphotic patients was 23.3% ± 5.81% versus 13.8% ± 9.83% for nonkyphotic patients. A significant association was found between the percentage of fatty infiltration and the PKD after 1 year ($P = 0.045$). The optimal fat cutoff between kyphotic and nonkyphotic patients was 23% ($P = 0.056$).

Conclusions: The present study demonstrated that patients with higher degree of fatty infiltration were associated with PKD. Based on our results, patients with increased cervical paraspinal degeneration may have increased risk of developing PKD. With this information, surgeons may be better equipped to predict the risk of PKD.

Keywords: Cervical laminoplasty, fat infiltration, paraspinal muscle, sarcopenia

INTRODUCTION

Sarcopenia is defined as the gradual loss of muscle mass and strength and is considered a manifestation of frailty.[1,2] It has been associated with several detrimental outcomes including functional decline, higher risk of falls, higher incidence of hospitalizations, and higher mortality rates.[3,4] Moreover, sarcopenia is associated with adverse postoperative outcomes.[5-7] Knowing this, there has been growing interest in assessing the effects of paraspinal sarcopenia on outcomes after spinal surgery.

Numerous studies have explored the relationship between paraspinal sarcopenia and postoperative outcomes following spine surgery for surgeries at various spinal levels.[8,9] A

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series of studies published by Pinter *et al*. have shown that sarcopenia is associated with worse patient-reported outcome measures in patients undergoing cervical spinal surgery.[10-12] In particular, higher-grade paraspinal sarcopenia was associated with worse patient-reported outcomes measures (PROMs) after cervical laminoplasty.

Although laminoplasty carries a low complication rate, approximately 20% of patients experience a loss of cervical lordosis or develop a kyphotic deformity postoperatively.[11] Since the natural curvature of the cervical spine prevents the spinal cord from migrating posteriorly, flattening or kyphotic curvature can cause the spinal cord to drape over the vertebral bodies, potentially impairing neurological function and resulting in adjacent segment disease, pain, or disability.[12,13] Therefore, pinpointing preoperative risk factors for the development of postlaminoplasty kyphotic deformity (PKD) is crucial. Such knowledge would enable surgeons to refine preoperative surgical decision-making and adapt treatment plans to avert this complication.

To that end, studies by Pinter *et al*. have utilized the Goutallier grade to provide a qualitative metric of sarcopenia within the paraspinal musculature. However, the Goutallier method is inherently qualitative and introduces bias into the assessment of sarcopenia of paraspinal musculature. Even with the use of multiple reviewers, this bias cannot be eradicated. The aims of our study thus were threefold. First, we assessed the relationship between preoperative fatty degeneration of the paraspinal muscles and the occurrence of postoperative kyphosis after cervical laminoplasty using the Goutallier grade of sarcopenia. Second, we augmented the Goutallier method by utilizing image segmentation software and a thresholding procedure to add a quantitative dimension to the measurement of paraspinal muscle fatty degeneration. Finally, we studied the association between these quantitative measurements of fatty infiltration and the occurrence of postoperative kyphosis after cervical laminoplasty.

MATERIALS AND METHODS

Data acquisition

After the Institutional Review Board (IRB) approval of a waiver of consent for this single-institution retrospective study (IRB 202009133), we reviewed the electronic health records of all adult patients who underwent unilateral expansive open-door cervical laminoplasty (CPT codes 6305 and 63051) at the C4-C6 vertebral levels for the treatment of cervical spondylotic myelopathy (CSM) at a single academic tertiary care center between January 1, 2018, and January 30, 2022. This study was performed following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[14]

Patients included in this study had a complete set of anteroposterior (AP) and lateral cervical radiographs 1 year after surgery as well as preoperative AP/lateral radiographs and magnetic resonance imaging (MRI) studies of the cervical spine. We excluded patients who were <18 years of age, underwent laminoplasty for diagnoses other than CSM, had undergone previous cervical spine surgery, did not have preoperative and 1-year postoperative cervical radiographs, or did not have a preoperative cervical spine MRI. Demographic variables collected included age, gender, body mass index (BMI), and occupation. Multiple frailty domains including comorbidities, cognitive ability, and overall functional status were assessed by calculating the Charlson Comorbidity Index (CCI), the 5 modified frailty index (5i-mFi), and the Risk Analysis Index (RAI-A), which are well-validated instruments to assess frailty in surgical patients.

Radiographic analysis of postlaminoplasty kyphotic deformity

Radiographic measures included the preoperative and postoperative C2-C7 Cobb angles. The outcome measure was defined as the development of PKD. PKD was defined as a loss of cervical lordosis of >10° when measuring the difference between the pre- and postoperative C2-C7 Cobb angles, as has been used in similar studies [Figure 1].[15-17]

Goutallier grade and qualitative fat infiltration image analysis

T2-weighted MRI studies were reviewed by two independent blinded reviewers to assign a Goutallier classification to the right- and left-sided multifidus muscles at the C5 and C6 levels. These levels captured the bulk of the multifidus and ensured consistency between reviewers. Goutallier

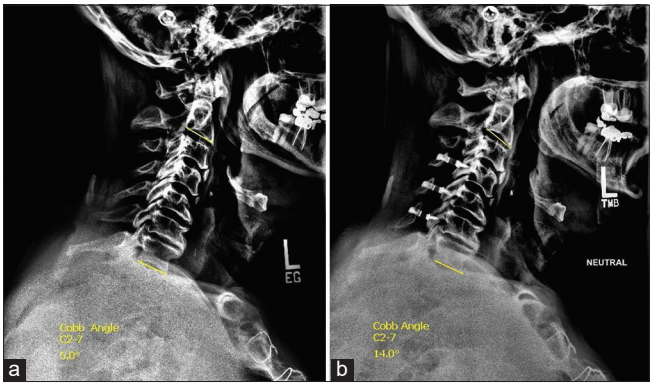

Figure 1: Radiographic assessment of the cervical spine in patients with cervical spondylotic myelopathy. (a) Preoperative X-rays in a 60-year-old male. (b) Postoperative X-rays in a 60-year-old male demonstrating kyphotic changes based on the C2-7 Cobb angle

classification for this study was assigned according to the methodology of other studies: Grade 0 if there were no visible fat streaks; Grade 1 if there were minimal fat streaks; Grade 2 if there was fat organized in clusters but the area of muscle was greater than fat; Grade 3 if fat was organized in clusters and areas of muscle and fat were present in approximately equal concentrations; and Grade 4 if fat was organized in clusters and the area of fat was greater than the area of muscle [Figure 2].[10] Each assessor evaluated both the right and the left multifidus muscles, and the averaged result was designated as the final Goutallier grade for each patient. The results were grouped as follows: Grade 0–1, Grade 1.5–2, and Grade 2.5–4.

Image segmentation and quantitative fat infiltration image analysis: manual image segmentation was performed utilizing the ITK-SNAP software (University of Pennsylvania, Philadelphia, PA, USA).[13] The two blinded assessors utilized T2 MRI scans to perform the fatty infiltration calculation of right- and left-sided multifidus muscle at the C5–C6 levels. This level was instrumented for all included patients. The assessors used one segmentation layer to capture the entire paraspinal musculature, multifidus included (Layer one). Subsequently, the assessors used the "Adaptive Brush" tool within ITK-SNAP to capture the left and right multifidus muscles in two separate layers (Layers two and three, respectively). Finally, the assessors used basic thresholding to highlight and count the number of voxels that corresponded to fat within each multifidus muscle (Layers four and five) [Figure 3]. After this analysis, calculations were performed to determine the percentage of fatty infiltration within each muscle: (# Voxels in Layer two/# Voxels in Layer two + Layer four) and (# Voxels in Layer three/# Voxels in Layer three + Layer five). The results for each side were then averaged to calculate the final fatty infiltration percentage for each patient.

Statistical analysis

Descriptive statistics were performed in R Studio (RStudio 2024.02.29, Boston, USA). For the qualitative study, a Chi-Squared and *post ho*c pairwise analysis of Goutallier groups (Grade 0–1.5, Grade 1.5–2.5, and Grade 2.5–4) and postoperative kyphotic status were performed in the R Studio (RStudio 2024.02.29, Boston, USA). Shapiro–Wilk testing demonstrated a non-Gaussian distribution of fat; therefore, a Mann–Whitney-U test was performed to evaluate the differences in the total fat percentage with postoperative kyphotic status. Optimal fat cutoff determination was attempted using the maximally selected rank statistics using the survminer package (RStudio 2024.02.29, Boston, USA).

RESULTS

We identified 44 patients who had the requisite sets of AP/lateral cervical radiographs and preoperative MRI scans. Four patients (9%) developed postoperative kyphosis. The cohort was 59.1% male, with a mean age of 62.9 ± 10.13 years. The mean BMI of the cohort was 28.8 ± 4.52. The mean CCI score for the cohort was 3.41 ± 2.51. The complete descriptive statistics for the cohort can be found in Table 1.

Qualitative fat infiltration

A total of 32 patients (72.7%) were classified as Goutallier 0–1.5 (Group one), 6 (13.6%) were Goutallier 1.5–2.5 (Group two), and 6 (13.6%) were Goutallier 2.5–4.0 (Group three). The characteristics of the patients in each group are shown in Table 2. Determination of Goutallier grade by the two assessors resulted in a correlation coefficient of 0.826 (Pearson, r^2), thus demonstrating high interrater reliability.

Chi-squared analyses with *post hoc* pairwise comparisons were conducted to analyze the relationship between the assigned Goutallier group and postoperative kyphotic status. There was a statistically significant difference in the frequency of postoperative kyphosis among the different groups ($P = 0.00085$). Results from the *post hoc* pairwise comparison revealed statistically significant differences between Group one and Group three ($P = 0.008$) [Figure 4]. The other variables studied in the kyphotic versus nonkyphotic groups [Table 1] and between the different Goutallier groups were not statistically significant [Table 2].

Quantitative fat infiltration

The average fatty infiltration percentage for kyphotic patients was 23.3% ± 5.81%. The average fatty infiltration percentage for nonkyphotic patients was 13.8% ± 9.83%.

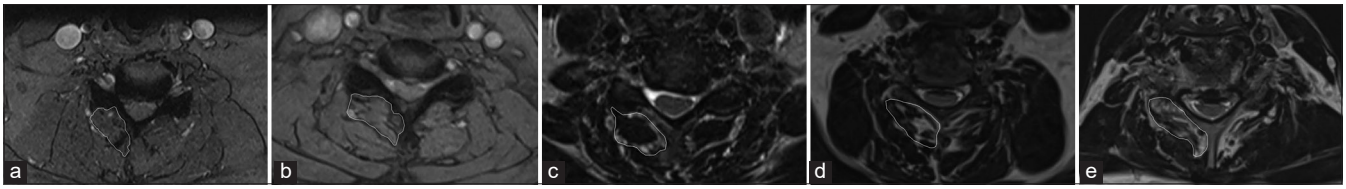

Figure 2: Axial T2-weighted magnetic resonance imaging at C5/C6 demonstrates Goutallier Grades 0-4 in the multifidus muscle (outlined in white): (a) No fat. (b) Minimal fat. (c) Muscle greater than fat. (d) Muscle equivalent to fat. (e) Fat greater than muscle

Figure 3: Manual segmentation of paraspinal muscles: (a) Layer 1, entire muscle group. (b) Layers 2-4, multifidus (green), semispinalis cervicis (yellow), semispinalis capitis (pink). (c) Thresholding identifies fat-representing voxels in multifidus (blue)

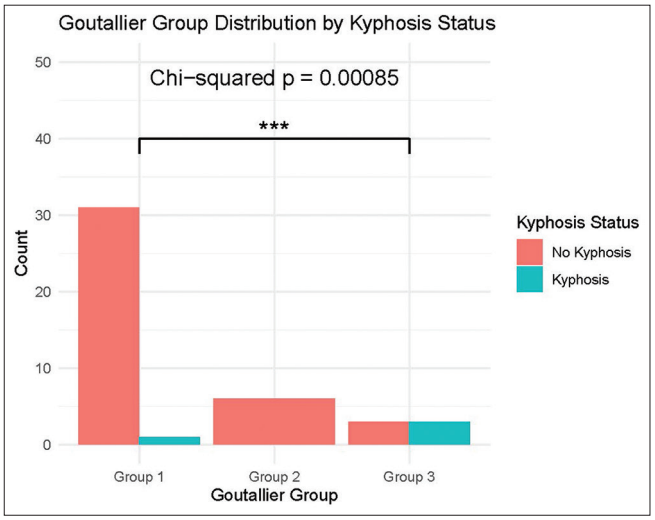

Figure 4: Bar plot demonstrating the distribution of kyphotic patients among the Goutallier groups. Chi-squared results with *post hoc* significance between Groups 1 and 3 are labeled (*P* = 0.00085)

To assess the differences in fat infiltration between the two groups (nonkyphotic vs. kyphotic), a Mann–Whitney U analysis was conducted. There was a statistically significant difference in fatty infiltration between the kyphotic and nonkyphotic groups ($P = 0.045$). Using maximally selected log-rank statistics, the optimal fatty cutoff point to separate kyphotic versus nonkyphotic patients was a fat percentage of 23% ($P = 0.056$) [Figure 5a and b].

DISCUSSION

Key results

The present study is the first to investigate whether an association exists between cervical paraspinal fatty degeneration as assessed on advanced imaging and postoperative kyphotic status. Moreover, this study used both qualitative and quantitative methods to assess fatty degeneration. The rate of postlaminoplasty kyphosis in our study was 9%, which reflects established rates in the literature.[18,19]

Qualitatively, our study demonstrated an association between Goutallier group and postoperative kyphosis. There were significant differences between Group one and Group three. These results suggest that the degree of a patient's preoperative fat infiltration can influence the development of postlaminoplasty kyphosis. We observed two patients who were designated Group one but who still developed kyphosis. Interestingly, these patients were both overweight, postmenopausal females who were noted to have facet arthropathy on imaging. This is important to highlight because fatty infiltration is likely not the sole factor that contributes to postoperative kyphosis. Literature has shown that certain demographic factors such as advanced age, duration of symptoms, and smoking status all contribute to postoperative kyphosis or axial symptoms in cervical spine patients.[5,20] These variables, however, were not statistically significant in our study. While increased BMI, postmenopausal status, osteoporosis, and facet arthropathy have not been specifically associated with the development of postoperative kyphosis, they are all contributing factors to a variety of spine pathologies.[21-23] Postmenopausal status is a major risk factor for osteoporosis and thus could be a contributor to associated spine pathologies as well.[24] The importance of this discussion is to demonstrate that a variety of clinical components may contribute to the likelihood of developing kyphosis after cervical laminoplasty and that clinicians should be cognizant of all clinical facets, including the degree of fat infiltration assessed in preoperative MRIs. Based on our study, if the cross-sectional area of fat is present in approximately equal concentrations compared to muscle (muscle = fat), or to a greater degree (muscle < fat), those patients should be considered high risk for postlaminoplasty kyphosis.

Quantitatively, our study demonstrated that there was a statistically significant relationship between the degree of fatty infiltration and postoperative kyphotic status after 1 year. This validates our hypothesis that patients with higher preoperative fatty infiltration of the cervical paraspinal musculature are at increased risk for the development of PKD. However, fatty infiltration may not be the sole factor that contributes to postoperative kyphosis, and the clinical risk assessment for this complication will probably need an integrative evaluation of multiple conditions, not just the

Table 1: Patient demographic and clinical information by kyphosis status

Variable	Value			*P*
	Overall, *n* (%)	No kyphotic deformity, *n* (%)	Kyphotic deformity, *n* (%)	
Number of patients	44	40 (90.9)	4 (9.1)	N/A
Sex (female)	18 (40.9)	15 (37.5)	3 (75.0)	0.288
Race				1.0
White race	35 (79.5)	31 (77.5)	4 (100)	N/A
Black or African American race	8 (18.18)	8 (20.0)	0	N/A
Asian	1 (2.3)	1 (2.5)	0	N/A
Mean age (years)	62.9±10.13	63.25±9.9	59.5±13.4	0.620
Mean BMI (kg/m^2)	28.84±4.52	29.10±4.58	26.19±3.17	0.171
Smoking status				1.0
Never smoker	20 (45.5)	18 (45.0)	2 (50.0)	N/A
Former smoker	15 (34.0)	14 (35.0)	1 (25.0)	N/A
Current smoker	9 (20.5)	8 (20.0)	1 (25.0)	N/A
Occupation				1.0
Currently employed	18 (40.9)	16 (40.0)	2 (50.0)	N/A
Retired/on disability	11 (25.0)	10 (25.0)	1 (25.0)	N/A
Not on file/not recorded	15 (34.1)	14 (35.0)	1 (25.0)	N/A
CCI	3.41±2.51	3.43±2.53	3.25±2.63	0.918
None (CCI=0)	3 (6.8)	3 (7.5)	0	1.0
Mild (CCI=1–2)	17 (38.6)	15 (37.5)	2 (50.0)	1.0
Moderate (CCI=3–4)	11 (25.0)	10 (25.0)	1 (25.0)	1.0
Severe (CCI ≥5)	13 (29.5)	12 (30.0)	1 (25.0)	1.0
RAI total	11.14±8.84	10.88±8.85	11.5±10.1	0.859
Not frail (RAI-A ≤10)	29 (65.9)	27 (67.5)	2 (50.0)	0.596
Prefrail (RAI-A=11–20)	9 (20.5)	7 (17.5)	2 (50.0)	0.180
Frail (RAI-A=21–30)	4 (9.1)	4 (10.0)	0	1.0
Severely frail (RAI-A ≥30)	2 (4.5)	2 (5.0)	0	1.0
5i-mFi total	1.39±1.13	1.45±1.15	1.5±0.50	0.273
Not frail (m5i-Fi=0)	10 (22.7)	9 (22.5)	1 (25.0)	1.0
Prefrail (m5i-Fi=1)	17 (38.6)	14 (35.0)	3 (75.0)	0.282
Frail (m5i-Fi=2)	9 (20.5)	9 (22.5)	0	0.566
Severely frail (m5i-Fi ≥2)	8 (18.2)	8 (20.0)	0	1.0
Goutallier grade groups				<0.01*
1	32 (72.7)	31 (77.5)	1 (25.0)	N/A
2	6 (13.6)	6 (15.0)	0	N/A
3	6 (13.6)	3 (7.50)	3 (75.0)	N/A
Fatty infiltration percentage	14.7±9.89	23.3±5.81	13.8±9.83	0.045

*Statistically significant. Values represent the number of patients, percentage of patients (%) or mean±SD per variable. CCI - Charlson comorbidity index; 5i-mFi - 5-item modified frailty index; RAI - Administrative risk analysis index; BMI - Body mass index; SD - Standard deviation; N/A - Not available

degree of paraspinal degeneration. We sought to investigate the cutoff point that defined an increased risk of kyphosis. While this result was not quite statistically significant ($P = 0.056$), it is a starting point for further evaluation in future studies.

Results from similar studies

The impact of sarcopenia has been extensively investigated in the lumbar spine.[14-17,25,26] In contrast, the literature assessing sarcopenia's impact on postoperative cervical spine surgery outcomes is limited and has gained interest only in the past few years. Pinter *et al*. found that increased cervical paraspinal degeneration was associated with better patient-reported outcomes after anterior cervical discectomy and fusion (ACDF).[10] Another study conducted by Pinter *et al*. demonstrated that those with severe paraspinal sarcopenia demonstrate less improvement in neck disability index (NDI) compared to their mild and moderate sarcopenic counterparts after posterior cervical discectomy and fusion (PCDF). These patients were also more likely to report worsening PROMs further underscoring the burden that sarcopenia places on patients.[11] A follow-up study conducted by the same researchers assessed 114 patients and demonstrated similar results in patients postlaminoplasty for degenerative cervical myelopathy.[12] Finally, Pinter *et al*. demonstrated that semispinalis cervicis sarcopenia is associated with worsening

Table 2: Patient demographics and clinical information by Goutallier grade groups

Variable	Group			*P*
	1 (0–1.5), *n* (%)	2 (1.5–2.5), *n* (%)	3 (2.5–4.0), *n* (%)	
Number of patients	32	6	6	
Sex (female)	12 (37.5)	3 (50.0)	3 (50.0)	0.694
Race				0.242
White race	26 (81.3)	3 (50.0)	6 (100)	N/A
Black or African American race	5 (15.6)	3 (50.0)	0	N/A
Asian	1 (3.1)	0	0	N/A
Mean age	62.59±10.5	63.5±5.43	64.0±13.13	0.814
Mean BMI (kg/m^3)	28.9±4.81	28.2±2.46	28.8±5.15	0.989
Smoking status				0.854
Never smoke	14 (43.8)	2 (33.3)	4 (66.6)	N/A
Former smoker	11 (34.3)	3 (50.0)	1 (16.7)	N/A
Current smoker	7 (21.9)	1 (16.7)	1 (16.7)	N/A
Occupation				0.539
Currently employed	14 (43.8)	1 (16.7)	3 (50.0)	N/A
Retired/on disability	9 (28.1)	1 (16.7)	1 (16.7)	N/A
Not on file/not recorded	9 (28.1)	4 (66.7)	2 (33.3)	N/A
CCI	3.38±2.73	3.67±1.75	3.33±2.16	0.384
None (CCI=0)	2 (6.3)	0	0	1
Mild (CCI=1–2)	14 (43.8)	1 (16.7)	3 (50.0)	0.606
Moderate (CCI=3–4)	7 (21.9)	3 (50.0)	1 (16.7)	0.413
Severe (CCI ≥5)	9 (28.1)	2 (33.3)	2 (33.3)	1
RAI total	11.3±9.04	13.7±9.69	7.5±6.89	0.394
Not frail (RAI-A ≤10)	6 (18.75)	1 (16.7)	3 (50.0)	0.235
Prefrail (RAI-A=11–20)	14 (43.75)	1 (16.7)	2 (33.3)	0.829
Frail (RAI-A=21–30)	6 (18.75)	3 (50.0)	0	0.165
Severely frail (RAI-A ≥30)	6 (18.75)	1 (16.7)	1 (16.7)	1
5i-mFi total	1.44±1.13	1.66±1.03	0.83±0.82	0.394
Not frail (m5i-Fi=0)	6 (18.75)	1 (16.7)	3 (50.0)	0.258
Prefrail (m5i-Fi=1)	14 (43.75)	1 (16.7)	2 (33.3)	0.613
Frail (m5i-Fi=2)	6 (18.75)	3 (50.0)	0	0.106
Severely frail (m5i-Fi ≥2)	6 (18.75)	1 (16.7)	1 (16.7)	1
Kyphotic deformity	1 (3.12)	0	3 (50.0)	0.013*
Fat infiltration	0.1311±0.09	0.1772±0.11	0.2017±0.10	0.211

*Statistically significant. Values represent the number of patients, the percentages, or mean±SD per variable. CCI - Charlson comorbidity index; 5i-mFi - 5-item modified frailty index; RAI - Administrative risk analysis index; BMI - Body mass index; SD - Standard deviation; N/A - Not available

cervicothoracic sagittal alignment parameters after posterior cervical fusion, including postoperative kyphosis.[27]

The studies by Pinter *et al*. elucidate the relationship between sarcopenia and postoperative outcomes. These relationships can either be positive, as demonstrated in ACDF patients, or negative, as in laminoplasty and PCDF patients. However, the majority of studies in this series only present patient-reported outcomes after cervical spinal surgery. Previously mentioned papers published by Eleswarapu *et al*. and Kim *et al*. assessed other radiographic metrics such as postoperative kyphosis and proximal junction failure, but these studies did not focus on the cervical spine.[14,17] In addition, these studies utilized cross-sectional muscle area as an assessment of sarcopenia. Our study addresses these gaps by evaluating a postoperative radiographic parameter in postcervical spine surgery patients. Moreover, we expand on the current standards of assessing sarcopenia using both qualitative and quantitative methods to accurately evaluate the degree of fatty infiltration in an effort to reduce operator biases.

Limitations

Our study has several limitations. First, it is retrospective in nature and only included 44 patients. When selecting subjects from the consecutive series of patients that underwent cervical laminoplasty for CSM, the lack of postoperative imaging 1 year after surgery was the main factor that precluded inclusion and may have led to cluster bias and possible truncation; this poses limitations to the generalizability of the findings. We hypothesize this was likely due to poor compliance to postoperative follow-up plans due to geographical barriers, socioeconomic limitations,

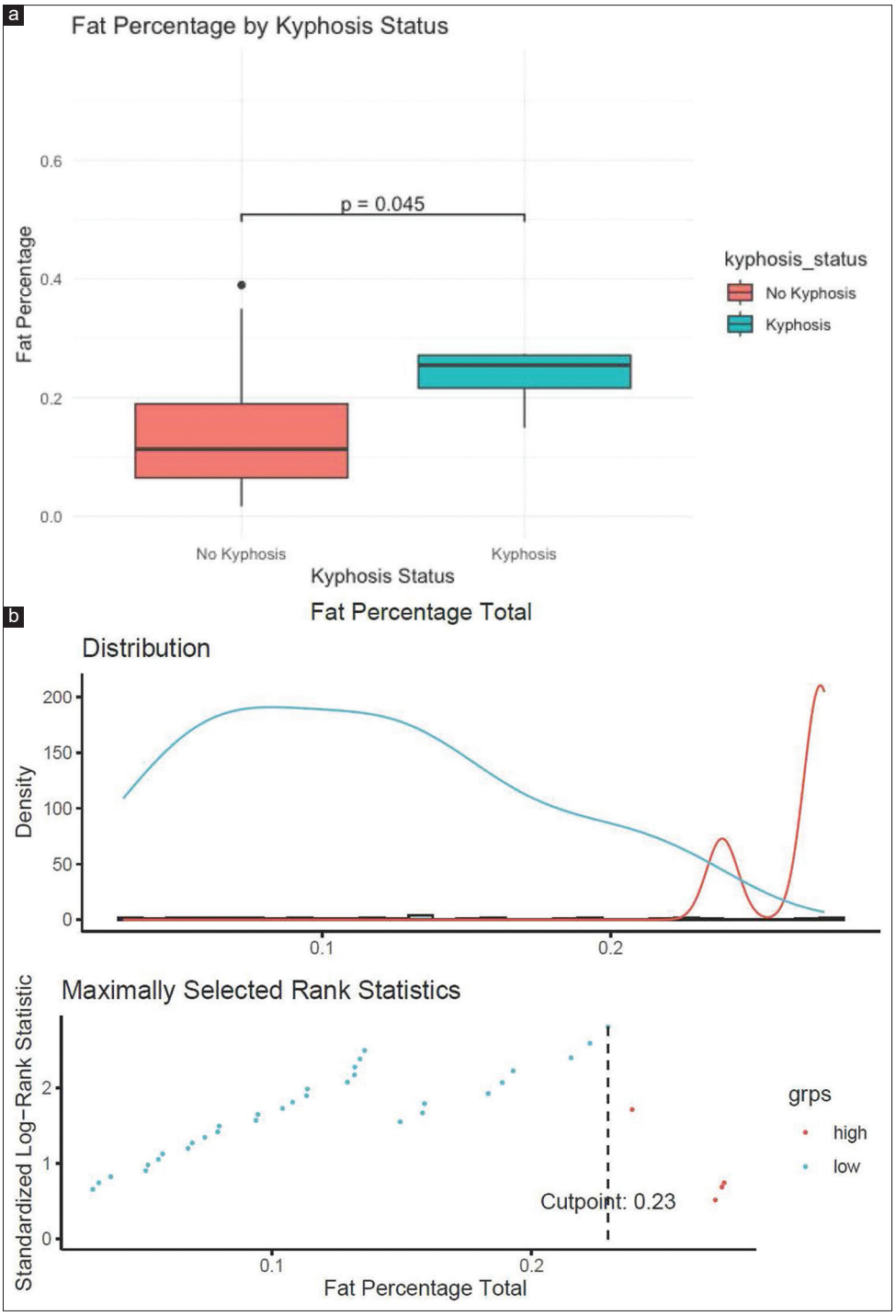

Figure 5: (a) Box and density plots show significant fat infiltration differences between groups. (b) Density plot highlights fat infiltration frequencies and the 0.23 cutoff separating groups, with a near-significant (*P* = 0.056)

and immediate postoperative experiences. Second, we did not perform a propensity score matching of the patients to reduce the confounding effect of patient variability on the analysis; this would have been ideal to identify other potential variables influencing the development of postoperative kyphosis, but it likely would have reduced the number of eligible patients even further. We were not successful in finding an explanatory variable that could inform why there was such extensive fatty infiltration. It is possible that patients developed kyphosis after the first postoperative year. Future prospective studies are recommended to incorporate more structured and enforced follow-up strategies to better assess the long-term outcomes of cervical laminoplasty in patients with CSM.

CONCLUSIONS

This study is the first to assess the association between cervical paraspinal muscle Goutallier grade and postoperative kyphosis outcomes following cervical laminoplasty. We used a novel technique for quantitatively assessing paraspinal fatty infiltration. The degree of fatty infiltration was positively associated with the occurrence of postoperative kyphosis. A larger cohort study with longer follow-up is needed to confirm the results of this study. However, the results from this study highlight the utility of investigating the impact of fatty degeneration, sarcopenia, and other comorbidities or markers of frailty on the development of postlaminoplasty kyphosis.

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Nil.

Conflicts of interest

Dr. Camilo Molina is a consultant for Augmedics, Stryker, DePuy Synthes, Kuros Biosciences.

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