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Posterolateral lumbar fusion: Relationship between computed tomography Hounsfield units and symptomatic pseudoarthrosis

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Abstract

Background: Assessment of bone quality can guide spinal surgery. However, surgeons infrequently evaluate bone quality in a quantitative manner. Recent literature suggests a role for computed tomography (CT) Hounsfield units (HUs) as a marker for bone quality. Limited data exist regarding its utility with respect to posterolateral lumbar fusion (PLF).

Methods: From fall 2010 to winter 2012, 10 patients underwent revision surgery for symptomatic pseudoarthrosis (defined as intractable pain associated with either radiographic evidence of nonunion or intraoperative evidence of nonunion) after a prior L4–S1 PLF. These patients were age-matched (±5 years) to 10 patients who underwent L4–S1 PLF with no clinical signs of pseudoarthrosis at 1-year follow-up. Available CT imaging (with or without instrumentation) was evaluated from L1 to L5 for the averaged HU. Data were pooled among L1–L3 values and between L4 and L5 values.

Results: Within the pseudoarthrosis group, the pooled L1–L3 HU value was similar to the pooled L4–L5 HU value (168.39 ± 22.84 HU vs. 166.98 ± 23.20 HU respectively, $P = 0.89$). The same pattern was observed for the control group (190.24 ± 37.13 HU vs. 201.89 ± 36.59 HU respectively, $P = 0.44$). On the other hand, the pooled L1–L3 and L4–L5 HU values were larger for the control group compared to the pseudoarthrosis group, with the pooled L4–L5 HU demonstrating statistical significance, $P = 0.01$.

Conclusion: Currently, CT imaging is typically not obtained prior to lumbar fusion. Results demonstrated that CT HU values were significantly larger for patients who did not exhibit symptomatic pseudoarthrosis at 1-year follow-up compared to those who required revision surgery. As such, CT HU values may serve as a predictor for bony fusion to guide surgical management of patients under consideration for PLF.

Key Words: Computed tomography, Hounsfield units, lumbar fusion, pseudoarthrosis

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INTRODUCTION

The incidence of pseudoarthrosis after posterolateral lumbar fusion (PLF) can be as high as 20%.[4,11] Potential risks factors for pseudoarthrosis can be divided into patient factors (smoking status,[5] comorbidities – diabetes,[11] steroid use, osteoporosis,[3] and use of nonsteroidal anti-inflammatory drugs) and surgical factors (adequate technique, posterior vs.

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anterior approaches, use of instrumentation,[6,7] use of various biologic adjuncts).[2] In particular, assessment of bone quality can provide insights for appropriate surgical management. Recent literature suggests a role for computed tomography (CT) Hounsfield units (HUs) as a marker for bone quality.[9,10] Limited data exist regarding its utility with respect to PLF. The objective of this study was to evaluate the relationship between CT HU and symptomatic pseudoarthrosis.

METHODS

The approval of the institutional board review at our hospital was obtained prior to the study.

Patients who underwent PLF (L4–S1) were retrospectively evaluated between fall 2010 to winter 2012. Ten patients exhibited symptomatic pseudoarthrosis (defined as intractable pain associated with either radiographic evidence of nonunion or intraoperative evidence of nonunion) and underwent revision surgery. These patients were age-matched (±5 years) to 10 patients who exhibited no clinical signs of pseudoarthrosis at 1 year follow-up. To be under consideration for the study, patients had to have CT imaging of the lumbar spine (within approximately 1 year of initial operation and/or revision) available for review. This criterion limited the patient population because CT imaging was seldom obtained prior to lumbar fusion. Patient clinical data (age, gender, body mass index [BMI], and extent of follow-up) were collected via chart review.

Available CT imaging (with or without instrumentation) was evaluated at the axial plane (cranial to the inferior endplate) from L1 to L5. This location has been employed in prior studies,[9,10] and appears distant from obvious artifacts if pedicle instrumentation was in place [Figure 1]. Via a picture archiving and communication system, the averaged HU was obtained based on the largest possible elliptical region of interest, excluding the cortical margins to prevent volume imaging [Figure 1]. Data were pooled (averaged) among L1–L3 values and between L4 and L5 values. The former represented global HU value given no surgical intentions at the L1–L3 levels; the latter represented the local HU value given intended fusion at L4–S1 levels.

Statistical analysis was performed with IBM SPSS 22 (Chicago, IL, USA). Interobserver and intraobserver reliability calculations were performed with the use of the interclass correlation coefficient (where 0 represents no agreement and 1 represents perfect agreement). A value >0.8 was considered an indication of excellent agreement. Student's *t*-test (two-tailed) was performed to compare for statistical significance between the control group and the pseudoarthrosis group.

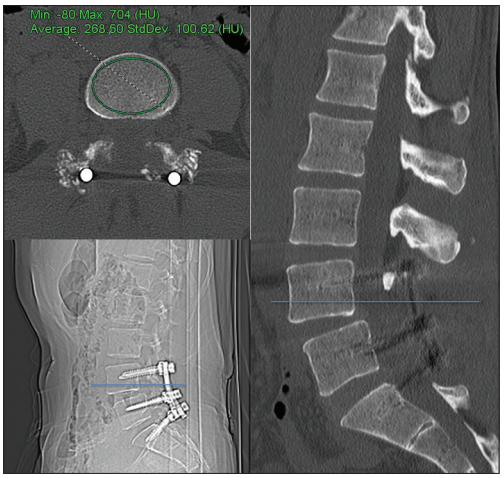

Figure 1: Example measurement of computed tomography Hounsfield unit value at caudal aspect of L4 body along axial plane

RESULTS

The pseudoarthrosis group and the control group each had 10 patients. Age remained comparable since the patients were age-matched for the study; BMIs were also comparable. Table 1 summarizes the patient demographics.

Within the pseudoarthrosis group, the pooled L1–L3 HU value was similar to the pooled L4–L5 HU value; the same pattern was observed for the control group. On the other hand, the pooled L1–L3 and L4–L5 HU values were larger for the control group compared to the pseudoarthrosis group, where the comparison between pooled L4–L5 HU values demonstrated statistical significance, $P = 0.01$. Table 2 summarizes the CT HU results. Intraobserver correlation coefficient was 0.957 (95% confidence interval [CI] 0.935–0.971). Interobserver correlation coefficient was 0.862 (95% CI 0.807–0.903).

DISCUSSION

Poor bone quality has been associated with pseudoarthrosis and instrumentation failure.[1] Historically, dual X-ray absorptiometry scores have been employed to evaluate bone health through evaluation of bone mineral density. However, the method does not directly evaluate the spinal vertebral bones. Moreover, spine surgeons infrequently evaluate bone health in a quantitative manner.[3] Recent literature suggests a role for CT HU as a marker for bone quality, with regards to bone mineral density,[9] fracture risk,[8] and compressive strength.[9]

Presumably, CT HU values may help guide successful spinal fusion. Limited literature exists regarding this topic. In 2014, Schreiber *et al.*[10] evaluated the relationship between CT HU values and lumbar interbody fusion. The study revolved around radiographic

Table 1: Patient demographics

	Pseudoarthrosis	Control	*P*
Total	10	10	N/A
Males	6	4	N/A
Females	4	6	N/A
Age (years)	44.40±12.14	45.40±10.65	0.85
BMI (kg/m^2)	30.01±6.43	32.29±8.5	0.51

BMI: Body mass index, N/A: Not available

Table 2: CT HU results

	Pseudoarthrosis	Control	*P*
Pooled L1-L3 HU*	168.39±22.84	190.24±37.13	0.13
Pooled L4-L5 HU*	166.98±23.20	201.89±36.59	0.01
P	0.89	0.44	

*Pooled value is the average HU across respective levels. HU: Hounsfield units, CT: Computed tomography

assessment for pseudoarthrosis. The group observed that levels, which achieved adequate fusion, exhibited significantly higher HU values than the nonunion levels (203.3 HU vs. 139.8 HU). In addition, the values within vertebral bodies rostral to a construct (considered a measure of global bone density) were also higher when adequate fusion was obtained (133.7 vs. 107.3).[10] When the entire construct was evaluated, HU values were significantly larger within the construct as compared to rostral vertebral bodies. Findings implied that CT HU values could be an indication of bony fusion, as well as a predictor for bony fusion.

Our study demonstrated that CT HU values were significantly larger for patients who did not exhibit symptomatic pseudoarthrosis at 1 year follow-up compared to those who underwent revision surgery. The results suggest that the parameter may be a useful adjunct to assess bone health and to guide surgical management for those patients considered for PLF. This complements the conclusions obtained by Schreiber *et al.* regarding lumbar interbody fusion. A few differences are noted. This study assessed symptomatic pseudoarthrosis while Schreiber *et al.* emphasized radiographic nonunion. Moreover, their measure of global bone density (HU values at rostal vertebral bodies) was equivalent to our L1–L3 pooled HU values; however, their values were lower compared to our values; this can be explained by an older patient population in their study. HU values diminish relatively linearly with each additional decade, ranging from an average 255.1 HU in the second decade of life to an average 78.7 HU in the ninth decade of life.[9]

CT imaging was seldom obtained for surgical management; available CT imaging was predominantly obtained for other medical concerns. This aspect limited the number of patients for the study. The decision to age-match the control group appeared valid given the small patient pool and the impact of age on CT HU values and bone mineral density. Unlike other prior studies,[9,10] which measured HU values at the cranial, middle, and caudal aspect of the vertebral body along axial planes, we only evaluated the caudal aspect of the body. This was justified because averaged HU values were comparable within the body at these three regions in a prior study.[9] Moreover, metal devices (pedicle instrumentation in our study) can significantly attenuate the radiation beam and exhibit high HU values; evaluation of the two rostral regions within the vertebral body would provide erroneous HU values if instrumentation was present.[9] Given that the pooled L1–L3 value and pooled L4–L5 value within each group were comparable, the presence of instrumentation (L4–S1) did not appear to influence the values at the caudal aspect of the vertebral body.

CONCLUSION

Currently, CT imaging is typically not obtained prior to lumbar fusion. Results demonstrated that CT HU values were significantly larger for patients who did not exhibit symptomatic pseudoarthrosis at 1 year follow-up compared to those who required revision surgery. As such, CT HU values may serve as a predictor for bony fusion to guide surgical management of patients under consideration for PLF.

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Conflicts of interest
There are no conflicts of interest.

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