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Quantification of Multifidus Atrophy and Fatty Infiltration Following a Minimally Invasive Microdiscectomy

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Abstract

Background
Multifidus muscle degeneration and atrophy have been demonstrated following traditional open spine surgery. The purpose of this study was to quantify multifidus muscle atrophy and fatty infiltration following a 1-level minimally invasive (MIS) lumbar discectomy.

Methods
Magnetic resonance imaging (MRI) of 24 patients who underwent a primary 1-level MIS microdiscectomy were reviewed. Demographics, operative levels, and time from surgery to imaging were assessed. Total and lean cross-sectional areas (CSA), T1-signal intensity ratio between the multifidus and psoas muscles, and lean-to-total CSA ratio were measured. Pre- and postoperative values were compared within each patient utilizing paired sample T-tests.

Results
The mean age was 47.8±14.2 years. MRI was obtained 182.5±194.4 days following index surgery. On the ipsilateral side, total CSA decreased at the index level (-4.9%) and the lean CSA decreased at the index (-6.2%), inferior pedicle (-13.0%), and inferior disc levels (-18.6%). On the contralateral side, no significant decreases in total or lean CSA were demonstrated. T1-signal intensity ratios increased at all levels, but the differences were not statistically significant. The lean-to-total CSA ratio was decreased at the superior disc (-5.2%), inferior pedicle (-8.4%), and inferior disc levels (-17.2%) on the ipsilateral side and at the contralateral inferior disc level (-5.3%).

Conclusions
Primary 1-level MIS discectomy results in minimal short-term atrophy and fatty infiltration of the multifidus at the index level. Total CSA atrophy was mainly confined to the ipsilateral side at the index level. Lean CSA atrophy was observed mainly at and below the index level on the ipsilateral side. Fatty infiltration, as measured by the lean-to-total CSA ratio, ranged 1.2-17.2% on the ipsilateral and 0-5.3% on the contralateral side with greater fat content demonstrated caudally to the surgical level.

Clinical Relevance
Overall, the majority of the multifidus muscle appears to be radiographically preserved following an MIS lumbar discectomy.

Introduction
The multifidus is a part of the deeper paramedian layer of paraspinal muscles that runs along the thoracolumbar spine. Many regard it to be the primary stabilizer of the lower lumbar spine.1,2 The anatomy of the multifidus muscle is complex with growing research interests in its normal physiology as well as its pathologic states.3,4 Specifically, the association between multifidus degeneration and chronic low back pain, degenerative disc disease, radiculopathy, and scoliosis have been demonstrated.5-9 Traditional midline posterior lumbar surgery remains a common means of spinal decompression and stabilization de-
spite well-demonstrated bilateral atrophy and fatty degeneration of the paraspinal muscles.\textsuperscript{10,11} These changes result in decreased biomechanical capacity of the trunk and potentially unfavorable long-term clinical outcomes.\textsuperscript{12-14}

A fundamental principle of minimally invasive surgery (MIS) is to reduce approach-related damage to the multifidus via muscle splitting techniques utilizing tubular retractors. Potential clinical benefits include decreased blood loss, pain, length of stay, and incidence of infection.\textsuperscript{15,16} There are limited studies that quantify in detail changes in the multifidus after MIS techniques.\textsuperscript{17-20} With the increased availability of high-resolution magnetic resonance imaging (MRI), non-invasive and reproducible cross-sectional information regarding the multifidus size and content can be studied in greater detail. The purpose of the current study is to quantify the atrophy and fatty infiltration of the multifidus muscle following a 1-level MIS lumbar decompression.

**Materials and Methods**

**Patient Population**

Institutional review board approval was obtained (ORA # 14051301). Patients who underwent MRI before and after primary 1-level MIS lumbar microdiscectomy by either of two fellowship-trained spine surgeons at a single institution were identified. Exclusion criteria included revision surgery, fusions, and irrigation/debridement for infections. Indications for postoperative imaging included either new onset or recurrent radicular symptoms.

**Surgical Techniques**

Common MIS microdiscectomy techniques have been described.\textsuperscript{21} The following surgical technique was utilized for all cases of primary procedures. The patient was placed in the prone position on a Jackson table. Fluoroscopy was utilized to identify and confirm the target level. A 1-2 cm incision was made lateral to the midline at the level of interest. Sequential dilation was performed until an 18 mm tubular retractor was placed as a surgical working channel. A burr and Kerrison rongeur were utilized to perform a hemilaminotomy of the superior lamina over the target disc space. The ligamentum flavum was resected and the traversing nerve root was identified and safely retracted medially. The disc space was localized and incised. Pituitary rongeurs were then utilized to perform the discectomy.

**Imaging Analysis**

In order to minimize radiographic artifact, all postoperative MRIs utilized a 3.0 Tesla machine. Measurements were performed with the institution’s image viewing software (Opal, Viztek, Garner, NC). Measurements included the total cross-sectional area (CSA), lean CSA, T1 signal intensity, ratio of lean-to-total CSA, and ratio of T1 signal intensity between the multifidus and psoas muscles. Atrophy was measured utilizing CSA measurements (mm\textsuperscript{2}) of the multifidus muscle using the axial T1-weighted sequences. The mean T1 signal intensity was quantified utilizing a grayscale histogram software with higher scores signifying greater intensity. The T1 signal intensity ratio between the multifidus muscle and the psoas muscle at each level were obtained and recorded. The ratio of lean-to-total CSA was utilized as an additional measurement of fatty infiltration as described in rotator cuff research.\textsuperscript{22} The measurements were performed at the ipsilateral and contralateral sides in reference to the surgical level and laterality. Measurements were made at the disc level above (supra disc), pedicle level above (supra pedicle), operative level (index), pedicle level below (infra pedicle), and the disc level below (infra disc) (Figure 1, Figure 2).

**Statistical Methods**

Statistical analysis was performed utilizing a paired
sample T-test. A p-value of <0.05 denoted statistical significance.

**Results**

Of the 24 patients included in the study, 14 were female and the mean age was 47.8±14.2 years. Demographics of the patient population are detailed in Table 1. Overall, the majority of patients underwent single-level decompression for radiculopathy at the L4-5 (58.3%, n=14) or L5-S1 (25.0%, n=6) disc level. Preoperative MRI was obtained at a mean of 2 months prior to the surgery while postoperative MRI was obtained at a mean of 6 months following surgery (Table 1).

On the ipsilateral side, the total and lean CSA were significantly decreased at the index level by 4.9% (p<0.01) and 6.2% (p<0.05), respectively. In addition, the lean CSA was significantly decreased at the inferior pedicle (-13.0%, p<0.01) and the inferior disc levels (-18.6%; p<0.01; Table 2). On the contralateral side, a decrease in the lean CSA at the index level was demonstrated, but was not statistically significant (Table 2).

The lean-to-total CSA ratios were significantly decreased at the superior disc (-5.2%, p<0.05), inferior pedicle (-8.4%, p<0.01), and the inferior disc levels (-17.2%, p<0.001) on the ipsilateral side (Table 2). On the contralateral side, the lean-to-total CSA ratio was significantly decreased by 5.3% at the inferior disc level (p<0.05; Table 2).

The T1 signal intensity ratios were increased at all levels following surgery with greater changes observed caudal to the microdiscectomy on the ipsilateral side. However, no significant differences were demonstrated in the T1 signal intensity ratios at any level (Table 2).

**Discussion**

Traditional open approaches to the lumbar spine are known to result in atrophy of the multifidus muscle. Published studies regarding multifidus muscle degeneration and fatty infiltration following MIS techniques have been limited. A study by Bresnahan et al demonstrated a significant increase in the paraspinal muscle cross sectional area on MRI in patients who underwent an MIS decompression.17 Although the imaging analysis was blinded, the results of postoperative paraspinal muscle hypertrophy were counterintuitive.

Fan et al compared the atrophy in the multifidus muscle in patients who underwent either an MIS or open posterior lumbar interbody fusion (PLIF).18 The authors demonstrated significantly lower multifidus muscle atrophy in the MIS cohort as compared to the open cohort. However, the indications for PLIF ranged from spondylolisthesis to large lumbar disc herniations.18 Similarly, Min et al demonstrated significantly decreased multifidus muscle degeneration following minimally invasive lumbar fusion when compared to open techniques.20 However, the open patients underwent either a PLIF or a posterolateral lumbar fusion (PLF) while all MIS patients underwent a transforminal lumbar interbody fusion.

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**Table 1. Patient Characteristics, Operative Levels, and Timing for Primary 1-level MIS Lumbar Decompression.**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>MIS (n=24)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Years, SD)</td>
<td>47.8 (14.2)</td>
</tr>
<tr>
<td>Female (n)</td>
<td>58.3% (14)</td>
</tr>
<tr>
<td>Operative Levels (%; n)</td>
<td></td>
</tr>
<tr>
<td>L2-L3</td>
<td>4.2% (1)</td>
</tr>
<tr>
<td>L3-L4</td>
<td>12.5% (3)</td>
</tr>
<tr>
<td>L4-L5</td>
<td>58.3% (14)</td>
</tr>
<tr>
<td>L5-S1</td>
<td>25.0% (6)</td>
</tr>
<tr>
<td>Time between Surgery and MRI</td>
<td></td>
</tr>
<tr>
<td>Preoperative MRI (Days, SD)</td>
<td>61.1 (55.4)</td>
</tr>
<tr>
<td>Postoperative MRI (Days, SD)</td>
<td>182.5 (194.4)</td>
</tr>
</tbody>
</table>

MIS: Minimally Invasive; SD: Standard Deviation; MRI: Magnetic Resonance Imaging.
As such, the purpose of this study was to rigorously quantify the multifidus muscle degeneration and fatty infiltration following a MIS lumbar microdiscectomy as demonstrated on MRI utilizing each patient as his or her own control.

The current study was able to quantify the anatomic changes to the multifidus muscle at an average of 6 months following a primary 1-level MIS lumbar decompression. Atrophy, as determined by the change in total CSA, was minimal and isolated to the index level. The lean CSA decreased most significantly at and below the index level, while fatty infiltration (as measured by the lean-to-total CSA ratio) increased at the adjacent levels. Additionally, a pattern of increasing atrophy and fatty infiltration caudal to the site of surgical intervention was demonstrated in the ipsilateral lean CSA and lean-to-total CSA ratio.

Although fatty degeneration, as measured by the T1 signal intensity ratio, demonstrated substantial percent change following surgery, no statistical significant differences were demonstrated between pre- and postoperative values. Recently, Zhi-Jun et al assessed the accuracy of this measurement in a rat model. The Pearson correlation coefficient demonstrated high correlation between T1 intensity ratios and histological fat scores ($r = 0.804$). Despite these findings, the current study only demonstrated a trend in postoperative T1 intensity ratio changes. This finding may be due to the wide range of values over a proportionally smaller surgical area attributed to MIS techniques in humans as compared to open multi-level techniques in a rat model.

Other studies have focused on T2 intensity ratios as an accurate reflection of multifidus muscle disruption. T2 signal intensity ratio measurements appear to be a better reflection of muscle edema and inflammation. These studies differ from the current

### Table 2. MRI-Documented Changes in Multifidus Muscle Following Primary 1-Level MIS Lumbar Decompression.

<table>
<thead>
<tr>
<th>Level</th>
<th>Ipsilateral Multifidus Total Cross Sectional Area (mm²)</th>
<th>Ipsilateral Multifidus Lean Cross Sectional Area (mm²)</th>
<th>Contralateral Multifidus Total Cross Sectional Area (mm²)</th>
<th>Contralateral Multifidus Lean Cross Sectional Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
<td>% Change</td>
<td>p-value</td>
</tr>
<tr>
<td>Supra Disc</td>
<td>794.0±233.0</td>
<td>811.6±259.0</td>
<td>+2.0%</td>
<td>0.38</td>
</tr>
<tr>
<td>Supra Pedicle</td>
<td>953.4±290.0</td>
<td>957.4±341.5</td>
<td>-1.3%</td>
<td>0.91</td>
</tr>
<tr>
<td>Index</td>
<td>1047.4±246.2</td>
<td>1000.3±238.7</td>
<td>-4.9%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Infra Pedicle</td>
<td>1148.3±288.9</td>
<td>1088.6±278.0</td>
<td>-5.3%</td>
<td>0.08</td>
</tr>
<tr>
<td>Infra Disc †</td>
<td>1135.5±245.8</td>
<td>1117.3±269.1</td>
<td>-1.6%</td>
<td>0.66</td>
</tr>
<tr>
<td>Supra Disc</td>
<td>787.9±224.5</td>
<td>778.3±212.7</td>
<td>+0.5%</td>
<td>0.65</td>
</tr>
<tr>
<td>Supra Pedicle</td>
<td>961.3±315.0</td>
<td>936.5±232.5</td>
<td>-0.8%</td>
<td>0.52</td>
</tr>
<tr>
<td>Index</td>
<td>1029.9±239.6</td>
<td>1021.5±213.9</td>
<td>+0.4%</td>
<td>0.71</td>
</tr>
<tr>
<td>Infra Pedicle</td>
<td>1121.7±264.4</td>
<td>1137.8±282.3</td>
<td>+1.7%</td>
<td>0.52</td>
</tr>
<tr>
<td>Infra Disc †</td>
<td>1117.4±215.4</td>
<td>1131.9±243.5</td>
<td>+1.1%</td>
<td>0.59</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Ipsilateral Multifidus Psoas T1 Signal Intensity Ratio</th>
<th>Ipsilateral Lean CSA to Total CSA Ratio</th>
<th>Contralateral Multifidus Psoas T1 Signal Intensity Ratio</th>
<th>Contralateral Lean CSA to Total CSA Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
<td>% Change</td>
<td>p-value</td>
</tr>
<tr>
<td>Supra Disc</td>
<td>1.81±0.63</td>
<td>1.98±0.72</td>
<td>+26.0%</td>
<td>0.43</td>
</tr>
<tr>
<td>Supra Pedicle</td>
<td>1.91±0.69</td>
<td>2.06±0.80</td>
<td>+21.7%</td>
<td>0.53</td>
</tr>
<tr>
<td>Index</td>
<td>2.23±0.91</td>
<td>2.27±0.89</td>
<td>+21.8%</td>
<td>0.90</td>
</tr>
<tr>
<td>Infra Pedicle</td>
<td>2.35±0.93</td>
<td>2.68±1.20</td>
<td>+35.0%</td>
<td>0.32</td>
</tr>
<tr>
<td>Infra Disc †</td>
<td>2.76±1.24</td>
<td>3.42±1.82</td>
<td>+51.7%</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Contralateral Multifidus Psoas T1 Signal Intensity Ratio</th>
<th>Contralateral Lean CSA to Total CSA Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
</tr>
<tr>
<td>Supra Disc</td>
<td>1.83±0.65</td>
<td>1.98±0.69</td>
</tr>
<tr>
<td>Supra Pedicle</td>
<td>1.90±0.69</td>
<td>1.94±0.64</td>
</tr>
<tr>
<td>Index</td>
<td>2.20±0.93</td>
<td>2.41±0.80</td>
</tr>
<tr>
<td>Infra Pedicle</td>
<td>2.48±1.04</td>
<td>2.65±1.03</td>
</tr>
<tr>
<td>Infra Disc †</td>
<td>2.80±1.31</td>
<td>3.24±1.75</td>
</tr>
</tbody>
</table>

†Patients whose operative levels included S1 were excluded from measurement at the inferior disc level. MIS: Minimally Invasive; MRI: Magnetic Resonance Imaging; Supra: Superior; Infra: Inferior; CSA: Cross Sectional Area.

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study in that the analysis was performed on patients who had undergone open procedures with short-
term follow up. In our analysis, the average postoper-
ative imaging was obtained 6 months after surgery,
which may have been well into the fibrotic regenera-
tive stage of the injury response minimizing the post-
surgical changes potentially observed on T2 imaging.

Fatty infiltration, as determined by the lean-to-total
CSA ratio, demonstrated post-surgical changes in
the current study. Given the variability in the shape
and CSA of the multifidus muscle between patients,
it appears intuitive that this ratio more accurately re-

clects true amount of fatty infiltration. Currently,
there is insufficient evidence regarding the utility of
the CSA ratio and its validity and reproducibility
should be the subject of future research. Neverthe-
less, this pattern of fatty infiltration does support
previous studies regarding the complex anatomy and
innervation of the multifidus muscle.3,4 In addition,
theses results are favorable when compared to data
regarding paraspinal anatomy after traditional open
posterior approaches.11,19

Despite small heterogeneous patient populations18,20
and some counterintuitive results17, studies compar-
ing changes to paraspinal musculature between open
and MIS procedures have consistently favored MIS
techniques. Bresnahan et al compared the paraspin-
al CSA in a cohort of 18 patients (9 undergoing open
vs. 9 undergoing microendoscopic decompression).
At an average of 16 months, the open patients
demonstrated an average decrease in CSA of 5.4%
while the microendoscopic decompression of steno-
sis (MEDS) grouped CSA ironically increased by
9.9%.17

There are clear limitations to the current study.
First, the sample size was relatively small, which may
have contributed to the lack of statistical significance
when comparing pre- and postoperative T1 signal in-
tensity ratios. However, consistent differences were
detected across all measurements. In addition, to the
best of our knowledge, the current study is the
largest radiographic analysis of patients undergoing
primary MIS microdiscectomies. Second, no clinical
correlations were made with the radiographic find-
ings. As such, the clinical significance of these radi-
ographic changes cannot be ascertained. Third, al-
though the pre- and postoperative measurements
were compared with each patient operating as their
own control in the paired sample T-test, the study
may have benefited from a control group that includ-
ed patients undergoing open decompression proce-
dures. Additionally, the date of the pre- and postop-
erative imaging was not standardized and varied be-
tween patients. Changes demonstrated in the postop-
erative imaging may have been independent of the
procedure and potentially due to the timing of the
postoperative imaging. In addition, two surgeons
performed the surgeries potentially introducing some
intra-operative variability amongst differing MIS

In summary, the findings of the current study sug-
gest primary 1-level MIS microdiscectomy results in
minimal atrophy and fatty infiltration to the multi-
fidus muscle at the index level on the ipsilateral side
of the intervention. Atrophy, as measured by the lean
CSA at the index level on the ipsilateral side, ranged
from 2.9-18.6% with increasing atrophy demonstrated
caudal to the index level. Fatty infiltration (best re-
presented by the decrease in the lean-to-total CSA ra-
tio) increased by 1.2% at the index level on the ipsilat-
eral side. However, more profound fatty infiltration
was demonstrated caudally toward the inferior disc
level, which increased by 17.2% and 5.3% on the ipsi-
lateral and contralateral sides, respectively.

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**Disclosures**

The authors declare no relevant financial disclosures.

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