The Quantitative Analysis of Back Muscle Degeneration after Posterior Lumbar Fusion:
Comparison of Minimally Invasive and Conventional Open Surgery

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Study Design: Prospective controlled study.

Purpose: The results of conventional open surgery was compared with those from minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) for lumbar fusion to determine which approach resulted in less postoperative paraspinal muscle degeneration.

Overview of Literature: MI TLIF is new surgical technique that appears to minimize iatrogenic injury. However, there aren't any reports yet that have quantitatively analyzed and proved whether there's difference in back muscle injury and degeneration between the minimally invasive surgery and conventional open surgery in more than 1 year follow-up after surgery.

Methods: This study examined a consecutive series of 48 patients who underwent lumbar fusion in our hospital during the period, March 2006 to March 2008, with a 1-year follow-up evaluation using MRI. There were 17 cases of conventional open surgery and 31 cases of MI-TLIF (31 cases of single segment fusion and 17 cases of multi-segment fusion). The digital images of the paravertebral back muscles were analyzed and compared using the T2-weighted axial images. The point of interest was the paraspinal muscle of the intervertebral disc level from L1 to L5. Picture archiving and communication system viewing software was used for quantitative analysis of the change in fat infiltration percentage and the change in cross-sectional area of the paraspinal muscle, before and after surgery.

Results: A comparison of the traditional posterior fusion method with MI-TLIF revealed single segment fusion to result in an average increase in fat infiltration in the paraspinal muscle of 4.30% and 1.37% and a decrease in cross-sectional area of 0.10 and 0.07 before and after surgery, respectively. Multi-segment fusion showed an average 7.90% and 2.79% increase in fat infiltration and a 0.16 and 0.10 decrease in cross-sectional area, respectively. Both single and multi segment fusion showed less change in the fat infiltration percentage and cross-sectional area, particularly in multi segment fusion. There was no significant difference between the two groups in terms of the radiologic results.

Conclusions: A comparison of conventional open surgery with MI-TLIF upon degeneration of the paraspinal muscle with a 1 year follow-up evaluation revealed that both single and multi segment fusion showed less change in fat infiltration percentage and cross-sectional area in the MI-TLIF but there was no significant difference between the two groups. This suggests that as time passes after surgery, there is no significant difference in the level of degeneration of the paraspinal muscle between surgical techniques.

Key Words: Paraspainal muscle, Fat degeneration, MRI, Posterior fusion

Introduction

One of the most important functions of the trunk muscle is to support the vertebral body. In particular, the back muscle, which is the extensor muscle of the lower lumber part, plays a pivotal role in the stability of the lumbar segment, and is essential in the dynamic control of segmentation movement. A direct injury to the back muscle during surgery for posterior fusion or an indirect injury from ischemia and denervation during the process of retracting the back muscle with long hours of excessive pressure are inevitable and might cause muscular atrophy and pain. This has become a major issue in failed back surgery syndrome[1]. Recently, with posterior vertebral surgery, there have been reports of a relationship between back muscle injury with an excessive muscle dissection[2] and the retraction time and pressure of the back muscle[3-5] from a spinous process and lamina through the histological, enzymological, radiological quantification of a back muscle injury and degeneration. As a solution for these issues, there has been increasing interest in neural decompression and interbody fusion that employ minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) minimizing soft tissue injury, peripheral tissue injury and loss of blood[6,7].

There are reports showing that the minimally invasive approach can reduce muscular injury and systemic inflammatory response compared to the temporal approach by serologically analyzing the degree of back muscle injury immediately after surgery[8]. However, there are no reports that have quantitatively analyzed and demonstrated a difference in back muscle injury and degeneration between minimally invasive surgery and conventional open surgery after a follow-up of more than 1 year after surgery.

Therefore, as the degree of comparison between tissues is excellent, the authors compared the results by quantitatively analyzing the degree of back muscle degeneration after posterior fusion according to the surgical approach by MRI, where measurements of the percentage fat infiltration of the skeletal muscles[9,10] and muscle mass[11] is possible through linkage with a range of software.

Materials and Methods

1. Research design and materials

For this study, the preoperative selection of subjects and those to be observed for postoperative back muscle degeneration was performed in a prospective manner. Forty eight patients had received posterior fusion of either a single or multi-segment with spinal stenosis at our hospital from March 2006 to March 2008 and were available for a 1 year MRI follow-up (Average of 12.7 months, 11 to 29 months). Among the patients, those with a history of spinal surgery, possible atrophy in the back muscle according to a preoperative MRI inspection or possible malignant tumor or infections in the spine were excluded.

There were 17 cases of conventional open surgery (10 cases of posterior lumbar interbody fusion, 7 cases of posterolateral fusion) and 31 cases of MI-TLIF. There were 31 cases of single segment fusion and 17 cases of multi-segment fusion (Table 1). In this study, there were many cases of multi-segment fusion in the group that underwent conventional open surgery and in cases of single segment fusion in the group that had undergone MI-TLIF. As the quantification analysis of back muscle degeneration can differ according to the approaches, the analysis was made by classifying the subjects into single segment and multi-segment fusions according to the number of fusion segments.

There were 17 men and 31 women with an average age at the time of surgery of 57 years (range, 30 to 77 years). The mean follow-up period was 18 months (range, 12 to 29 months). All procedures were performed by a single surgeon at the same institution.

2. Surgical methods

For conventional open surgery, a horizontal skin incision was performed along the center line around the lesion, and a muscular dissection and detachment were performed from the spinous process and lamina using bipolar electrocautery so that the lower lamina and outer border of the facet joint could be seen. Posterior decompression, disectomy, interbody fusion and fixation of a vertebral body screw were then performed with the muscle being pulled using a Cod-

Table 1. Case analysis

	All group	Conventional open surgery	MI-TLIF
Total (case)	48	17	31
One level	31	6	25
Multi level	17	11	6

MI-TLIF: minimally invasive transforaminal lumbar interbody fusion.

man spinal retractor.

For MI-TLIF, two paramedian skin incisions, 2.5 cm in length, were made on the site approximately 2.5 cm apart from the midline, and the approach was made between the muscles reaching up to the lamina and facet joint through a blunt dissection of the multifidus and longissimus muscle. When the facet joint was exposed, facet joint removal, posterior soft tissue decompression, disc removal and interbody fusion were performed with the muscle being pulled using the tubular retractor system. When the vertebral body screw was fixed, fixation of percutaneous vertebral body screw was performed by C-arm fluoroscopy through the multifidus and longissimus muscle.

Walking began by applying a lumbosacral orthoses from 1 day after surgery, and was worn for 3 months by observing the fusion state by X-rays in the outpatient follow-up.

3. Image acquisition and analysis

MRI was performed using a 1.5-Tesla model (Signa; General Electric Medical Systems, Milwaukee, WI, USA) in the supine position with the legs spread and the lumbar area in the neutral position. An axial plane image was acquired with 3 sections per disc range in the T2 enhanced image (TE/TR 122/4000, DFOV 280.0 mm, NEX 4, slice thickness/gap 4 mm/1 mm) so that each disc become horizontal by setting the position of the lumbar disc in the sagittal plane. Among these, images of the center site on the disc in the sagittal plane were taken. Postoperative MRI was performed approximately 1 year after surgery when postoperative edema and swelling of the muscles had disappeared. To minimize the intervention of the vertebral pedicle screw and metal rods artifact of the fusion site, the uppermost axial
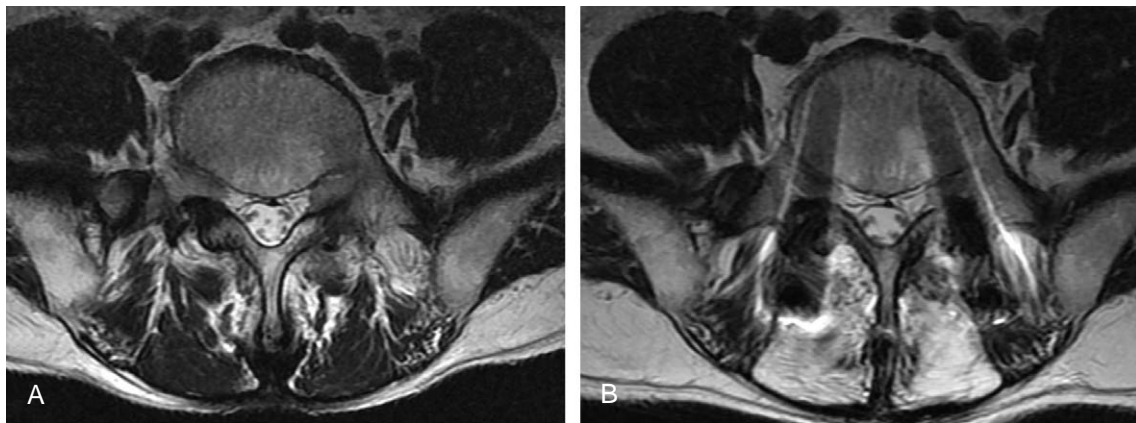

Fig. 1. Magnetic resonance imaging of the preoperative shows healthy back muscle (**A**), whereas that of the postoperative shows muscular atrophy and fat infiltration (**B**).
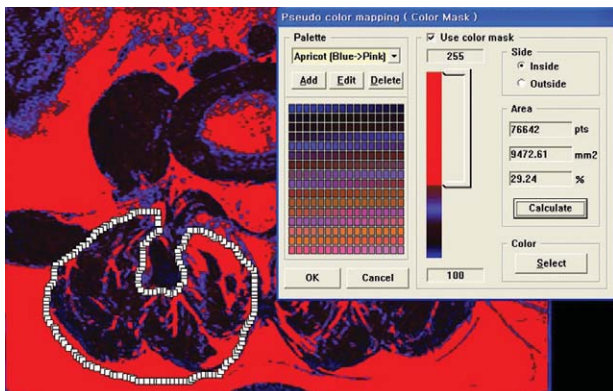

Fig. 2. Bright pixels of fat tissue in the MR images were colored in red (darker color in the black and white version) using a pseudocoloring technique. The percentage of red pixel area(fat components) in the muscle compartment was calculated and read in the signal intensity histogram.
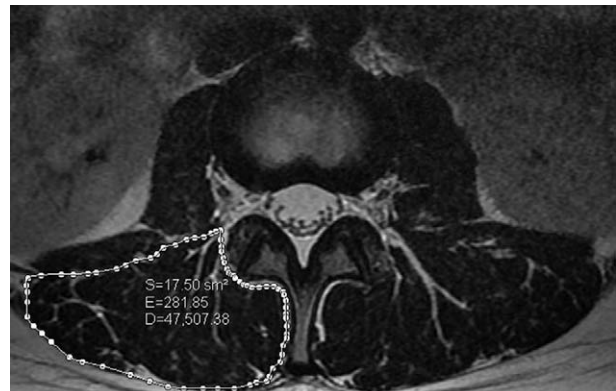

Fig. 3. Areas of the right-sided back muscle were measured using the picture archiving and communication system viewing software tools.

plane image were selected instead of the middle part of the disc (Fig. 1).

After scanning, the images were stored in the form of a DICOM file using image storage and transmission system software. The images were analyzed using MultiVox (Tech-Heim, Seoul, Korea) and PiView (Infinitt, Seoul, Korea) digital image software.

The areas of interest of the back muscle were established on the lumbar's T2 enhanced axial image at the L1-L2, L2-L3, L3-L4 and L4-L5 disc level, and the proportion for each cross-sectional area and fat infiltration were measured and analyzed. The L5-S1 level was not included because the axial cutting gantry was obstructed by the iliac crest and the muscular anatomy was quite different from the upper levels. The regions of interest were outlined with a graphic cursor around the back muscle on the right side, as well as on the intervertebral disc at each level. The fascia thoracolumbalis was traced down laterally and anteriorly to the dorsal side of the quadratus lumborum, followed by the posterior surface of the facet and lamina, and lateral margin of the spinous process. In the areas of interest, the cross-sectional area of the back muscle before and after surgery at each disc level was measured. Their average values were obtained and the degree of preoperative and postoperative back muscle cross-sectional area was calculated to determine if there was a difference between the groups (Fig. 2). The percentage muscle fat infiltration was measured using the pseudo coloring technique[12], and was also compared to determine if there was a difference in the change from before and after surgery between the groups (Fig. 3).

One radiological specialist and two orthopedic specialists analyzed the images. Each value was measured 3 times by each specialist with an at least 2 week interval between measurements.

4. Statistical analysis

An independent specimen t-test was used to make a comparison between each group and determine the statistical significance using SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA). A p-value <0.05 level was considered significant. The degree of agreement between the measurers was evaluated using the intraclasscorrelation coefficients (ICCs) introduced by Shrout and Fleiss[13].

Results

The degree of postoperative back muscle fat degeneration in the conventional open surgery and MI-TLIF group increased 6.63% and 2.14%, respectively, compared to the preoperative figures, whereas the cross-sectional area decreased 0.14 and 0.08, respectively. For single segment fusion, the degree of postoperative back muscle fat degeneration increased 4.30% and 1.37%, respectively, compared to the preoperative figures, whereas the cross-sectional area decreased 0.10 and 0.07, respectively. For multi-segment fusion, the degree of postoperative back muscle fat degeneration increased 7.90% and 2.79%, respectively, compared to the preoperative figures, whereas the cross-sectional area decreased 0.16 and 0.10, respectively (Table 2). Although the difference in degeneration measurements between the approaches were larger in the group that had undergone multi-segment fusion compared to the group that had undergone single segment fusion, the difference was not significant (p>0.05).

Table 2. The postoperative changes of back muscle on the conventional open surgery and minimally invasive transforaminal lumbar interbody fusion (MI-TLIF)

Variables	Conventional open surgery	MI-TLIF	p-value
Total			
Percentage of fat infiltration (%)	6.63±1.32	2.14±0.43	0.124
Relative cross-section area	-0.14±0.02	-0.08±0.01	0.175
One level			
Percentage of fat infiltration (%)	4.30±0.85	1.37±0.28	0.242
Relative cross-section area	-0.10±0.02	-0.07±0.01	0.288
Multi level			
Percentage of fat infiltration (%)	7.90±1.68	2.79±0.56	0.109
Relative cross-section area	-0.16±0.03	-0.10±0.01	0.116

* It were compared and analyzed by obtaining the total average value.

Discussion

In performing spinal fusion, there are many factors that might cause iatrogenic and degenerative changes to the back muscle. In particular, conventional open surgery can cause ischemia and denervation of the back muscle due to the need to make a long skin incision and also from the long hours of excessive pressure during the process of retracting the back muscle from the spinous process[1,2]. According to Kawaguchi et al.[3-5], back muscle injury at the time of posterior lumbar surgery is related to the operation time and retraction pressure. Therefore, it is recommended that the retraction be released for 5 minutes after 1 hour of retraction to prevent serious back muscle injury. Gejo et al.[14] also reported that the muscle retraction time influences the osteoperative back muscle function, and more than 2 hours pressure after retraction is believed to reduce the flow of capillary vessels, causing ischemic intramuscular changes[15-17]. Recently, as a solution for these issues, MI-TLIF has attracted considerable attention because it minimizes the level of soft tissue injury during surgery, surrounding muscle injury and blood loss during surgery[6,7]. Stevens et al.[18] compared the pressure applied to the muscles between the two approaches using a cadaver with a minimally invasive approach and reported a lower value with MI-TLIF.

In this study, a relatively long skin incision was applied to detach the back muscle from the bones, which is known as conventional open surgery, and considerable pressure was applied for many hours when all surgical methods were performed to retract both sides of the back muscle, which may cause injury or degeneration. On the other hand, a relatively short skin incision was made in MI-TLIF with a blunt dissection of the space between the muscles, which reduces the direct muscle injury, and the time for back muscle retraction is relatively short and there is a lower degree of pressure because the surgery is performed through 2 incisions on the site. Therefore, methods to quantify them have been examined with the aim of reducing the level of back muscle degeneration.

Hyun et al.[19] reported that the paramedian interfascial approach may preserve the back muscle even more by comparing the degree of back muscle injury according to the midline and paramedian approaches in lumbar fusion through postoperative quantification of back muscle mass using Computed tomography in 26 patients. However, computed tomography has difficulty in observing fat infiltra-

tions, degenerative changes, and internal structures in patients who have undergone fixation by inserting metallic objects due to the artifacts[20]. Therefore, many attempts have been made to evaluate the degree of muscle injury by measuring the degree of back muscle injury with a serological evaluation after diverse lumbar surgeries[1,21]. Kim et al.[8] reported that in lumbar fusion, the minimally invasive approach contributes considerably to reducing the level of postoperative muscular injury and systemic inflammatory response compared to the temporary approach through quantitative analysis that employs serum enzymes, such as creatine phosphokinase, inflammatory cytokine etc. After operating on 17 cases of MI-TLIF and 18 cases of posterior lumber fusion (PLF), Starkweather et al.[22] reported that after a 6-week follow-up visit, the Interleukin-6 levels were also significantly higher in the MI-TLIF group than in those patients who had undergone PLF, which may be an indicator of ongoing nerve regeneration and healing. Serological analysis may be used to evaluate an immediate postoperative muscular injury[21]. However, as time passes after the injury, metabolic equilibrium is formed where the figures are normalized making a long term observation difficult. Another study measured the degree of back muscle degeneration using MRI[12,23,24]. MRI is not only capable of measuring the muscle mass[9] but can also calculate the fat content of the skeletal muscles[10,11] thus enabling measurements of the degree of fat infiltration before and after surgery. After surgery using the traditional and minimally invasive approaches in 4 cases each, and carrying out a follow up evaluation of the extent of damage and edema in the multifidus muscle using MRI, Stevens et al.[18] reported a remarkable decrease in edema of the multifidus muscle but no significant difference in muscle contraction.

In this experiment study, in 48 cases in whom conventional open surgery and MI-TLIF had been performed, a quantitative analysis of the degenerative changes in the back muscle after 1 year revealed that MI-TLIF is effective in diminishing the changes in the percentile value of fat infiltration of the back muscle and the proportion of cross-sectional area compared to the conventional open surgery. In particular, in a group where a multi-segment fusion had been performed, the difference in the surgical approach was clear as compared to the group where a single segment fusion had been performed. However, the difference was not significant. In addition to the direct intraoperative injury to the back muscle, factors, such as the postoperative bed rest, period of brace use and degree of activity, should also

affect the degenerative changes in the back muscle[25,26]. In addition, from a long-term perspective, postoperative management might play a role as the key parameter for the degeneration of the back muscle.

A radiologic evaluation has limitations in accurately reflecting the actual clinical status. Therefore, further study will be needed to analyze the clinical assessment specifications and muscle activity. In this study, it could not be demonstrated whether the degree of back muscle degeneration reached statistical significance in both groups. Follow-up studies are warranted because of the possibility that this might have originated from a type II error (β error)[27] due to the small sample size.

Conclusions

The MI-TLIF is a method that minimizes damage to the soft tissue, regional muscles and blood loss immediately after surgery. However, after a period of more than 1 year, there was no significant difference in the paraspinal degenerative changes between the two techniques.

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