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Original Article

Anterior to Psoas Fusion versus Minimally Invasive Transforaminal Fusion with Cortical Bone Trajectory Fixation for Single-Level Lumbar Degenerative Disc Disease

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SUMMARY

Objective: To compare the clinical and radiological outcomes between an anterior to psoas (ATP) approach combined with cortical bone trajectory (CBT) fixation (ATP group) and minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) combined with CBT fixation (MI-TLIF group) for treating patients with lumbar degenerative disc disease and instability.
Methods: This retrospective study included patients who underwent interbody fusion and internal fixation between May 1, 2019, and September 30, 2020, using the ATP or MI-TLIF approach to treat degenerative lumbar disc disease and instability. The visual analog scale (VAS) score, Oswestry Disability Index (ODI) results, blood loss, operation time, complications, and bony fusion were analyzed and compared to understand clinical outcomes. Clinical and radiologic follow-up for all patients was at least 12 months.
Results: The ATP approach combined with CBT fixation resulted in less blood loss, earlier reduced VAS scores, better ODI scores, but longer operation time. At 12 months, the fusion rates in the ATP and MI-TLIF groups were 90% (18/20) and 72% (13/18), respectively.
Conclusion: Our results show that the ATP approach combined with CBT fixation had the advantage of less blood loss, earlier recovery in VAS scores, and better ODI than in MI-TLIF. Indirect and direct decompression could be successfully integrated by the ATP approach combined with CBT fixation and laminectomy.

1. Introduction

The anterior to psoas (ATP) approach and minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) are commonly used for the treatment of spinal disorders. In recent years, shorter hospital stays and quicker return to work have become important outcomes for patients who are undergoing surgery. Therefore, the development of new techniques has attempted to shorten the operation time and achieve faster recovery with reduced operation complications[1] while preventing iatrogenic injury and postoperative morbidity. In 1982, Harms and Rolinger reported on a new technique via the transforaminal route to achieve the insertion of an interbody cage filled with bone graft, termed TLIF.[2] Previously, Mayer introduced the ATP approach for the same purpose.[3] In 2012, Silvestre et al. reported that the use of the ATP approach was successful in 179 patients with positive results.[4] Compared with other surgical procedures, the ATP approach has several advantages including indirect decompression of the neural elements by restoring disc height, less risk of direct neural injury, less severe invasion of the psoas muscle and lumbar plexus, direct visualization of sensory nerves and other important anatomical structures, and consistent access to the L4–L5 level in cases with a high-riding pelvis.[5] However, there is no clear evidence to indicate whether ATP or TLIF is the better option for patients based on patient outcomes. Furthermore, both ATP and TLIF can be conducted using mini-open or minimally invasive approaches.[6,7]

Midline lumbar fusion (MIDLF) using fixation of the cortical bone trajectory (CBT) has been associated with ATP and TLIF and is regarded as an essential factor in their success. Specifically, Santoni et al. (2009) reported on the improvements in CBT screw technology regarding their holding force. According to his clinical experience, results with the new CBT screw were superior compared to the use of the pedicle screw[8] based on more efficient fixation which may decrease the influence of cancellous bone during the operation and entry points that are much closer to the midline. They also found that laminectomy and a minimally invasive approach could be performed in parallel; namely, the problems of lumbar stenosis and instability could be solved during a single operation. The ATP approach can be used to treat mild to moderate lumbar stenosis.[9] Our hypothesis is that the ATP approach combined with CBT fixation and laminectomy can be utilized in decompression for lumbar stenosis with faster fusion and better recovery outcomes for the treatment of degenerative lumbar disc disease. To investigate this hypothesis, we used several techniques to monitor decompression status, including

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neurological examination, and computed tomography (CT) of the spine. We also recorded the difference in the amount of blood loss, the operation time, visual analog scale (VAS)[10] scores and Oswestry Disability Index (ODI)[11] in the ATP and TLIF groups to determine the recovery status from the operation.

To our knowledge, there is little evidence based on patient outcomes to determine whether the ATP approach combined with CBT fixation is superior to MI-TLIF combined with CBT fixation. Therefore, this study aimed to compare the two approaches using radiographic and clinical data.

2. Methods and materials

This study was approved by the Institutional Review Board of MacKay Memorial Hospital (21MMHIS008e). Patients from May 1, 2019, to Sep 30, 2020, who underwent an ATP procedure with CBT fixation (ATP group) or MI-TLIF procedure with CBT fixation (MI-TLIF group) were included in the initial chart review.

The inclusion criteria were patients older than 18 years who suffered from lumbar spondylolisthesis grade I, recurrent herniated intervertebral disc (HIVD) after laminectomy and discectomy, and lumbar stenosis with neurological symptoms. The exclusion criteria were patients with previous extensive retroperitoneal surgery (e.g., renal surgery), transitional anatomy when targeting L4–5 because a sacralized L5 may contain variant psoas anatomy and an anteriorly displaced lumbar plexus, and liver cirrhosis with ascites. According to the criteria, 20 patients (male [m]:female [f] = 10:10), age (range: 37–80 y, 57.3 ± 11.6 y) in the ATP group and 18 patients (m:f = 6:12), age (range: 27–78 y, 66.1 ± 13.4 y) in the MI-TLIF group were included in this study. All patients who underwent internal fixation for one level of lumbar degenerative disease were followed up regularly for more than 12 months. Intraoperative data including blood loss, complications (CSF leakage, neurological deficits, and infection), and operation time were collected. The VAS scores, and ODI were evaluated at pre-operation and 2, 4, and 12 weeks after operation. After the operation, the radiographic outcomes on fusion status was evaluated at 12 months by CT scan.

2.1. Surgical techniques

2.1.1. ATP approach

The ATP approach for degenerative lumbar disease treatment was first described by Michael et al. in 1997[3] and is suitable for levels L2–L5. The patients were in the lateral decubitus position with the left side up for the anterior-lateral approach (Figure 1). The lateral decubitus and incision were performed based on the position and angulation of the disc upon image intensification while the patient was positioned for the operation.[12] Neuromonitoring was not necessary because the anatomical corridor anterior to the psoas muscle was used for access.[13] The patient's posture was important for obtaining a true lateral image of the lumbar spine. In addition, an axillary roll was used to bend the patient's hips and knees to relax the psoas muscle and nerve fibers inside. Next, we identified and marked the location of the anterior superior iliac spine, the contour of the iliac crest, and the target disc using fluoroscopy (C-arm). The incision was approximately 4 to 6 cm in length from the anterior superior iliac spine along the pelvis. Using fingers for blunt dissection, the retroperitoneal space was approached using the abdominal external oblique muscle, internal oblique muscle, and transversalis muscle with deep transversalis fascia in the back. Identifying the psoas muscle using the fingers and then finding the retroperitoneal fat using a peanut that was prepared for the target disc. The self-retractor was placed using the guide pin and discectomy was performed. After the space of the cage was filled with demineralized bone matrix (DBM), the chosen cage was inserted into the prepared disc space.

2.1.2. MI-TLIF

Under general anesthesia, the patient was placed in the prone position for MI-TLIF and a midline incision was used. Next, unilateral laminectomy and inferior facetectomy were adapted to enter the spinal canal. The MI-TLIF approach provided direct and unilateral access to the intervertebral foraminal space. Therefore, opening the neural foramen on one side only, the possibility of damage to important anatomical structures such as nerve roots, dura, and ligamentum flavum was decreased. After the target disc was identified and the disc was prepared by discectomy, the size of the cage was determined using the measuring tools and C-arm. After the cage space was filled with DBM, the cage was inserted into the prepared disc space.

2.1.3. CBT screws placement

For the CBT screws, the patients in the ATP group would be changed their position into the prone position. Then, a midline incision of approximately 5 cm was made over the spinous processes at the affected level in the ATP group. There was no additional wound was made for patients in the MI-TLIF group. Along the spinous process, bilateral muscle dissection to the lamina and the lateral edge of the pars interarticularis was achieved. Then, four pilot holes for the CBT screw entry points were drilled under C-arm.[8] Decompressive laminectomy was applied to patients with moderate to severe lumbar stenosis in the ATP group (Figure 2). Then, the screws were placed under C-arm.

2.2. Fusion evaluation

Fusion status was evaluated at 12 months using a CT scan. The

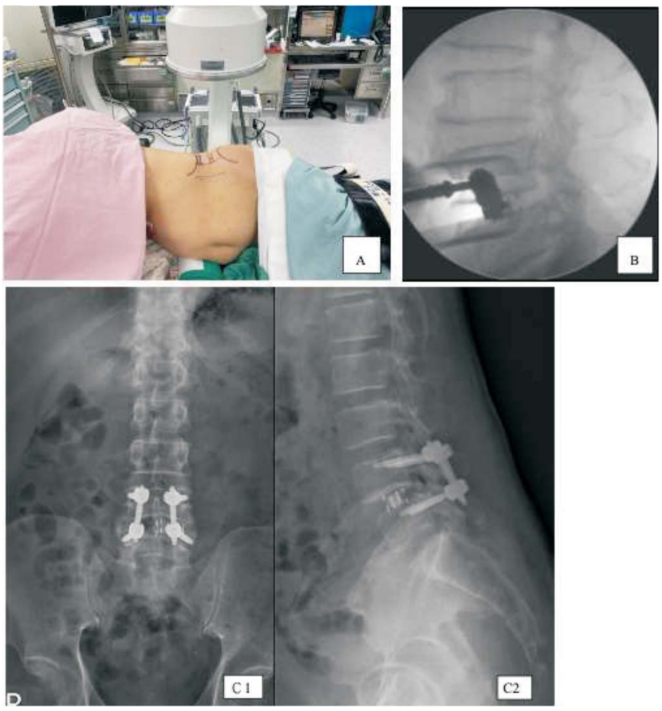

Figure 1. Preparation of patient's posture and pictures of instrumenton ATP group. A. The patient is in a right lateral decubitus position and slightly bent. B. The cage is inserted into the disc space and the true lateral view of the spine by C-arm is confirmed. C1 and C2. The cortical bone trajectory screws and cage are placed.

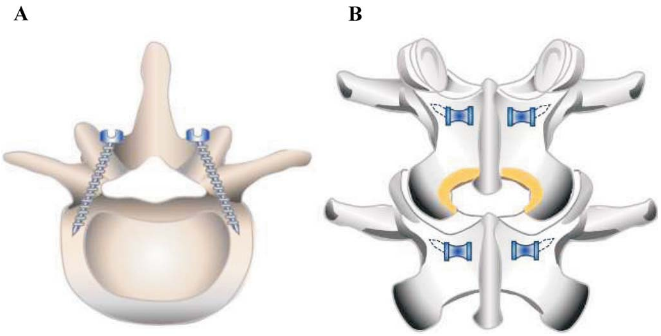

Figure 2. The application of CBT screws (blue) and partial laminectomy (yellow). A. The application of CBT screws (axial view). B. The partial laminectomy in ATP group (posterior view).

fusion status was evaluated using the Bridwell fusion grading system (grade 1, completely remodeled with trabeculae across the disc space; grade 2, graft intact with no lucent lines seen between graft and adjacent endplates; grade 3, graft intact, but a radiolucent line was seen between the graft and an adjacent endplate; and grade 4, lucency along the entire border of the graft, or lucency around a pedicle screw or subsidence of the graft).[14] Grade 1 was classified as a positive fusion, grade 2 was inconclusive and observed for more time, and grades 3 and 4 were classified as nonunion status.

2.3. Statistical analysis

The Student's t-test for continuous variables and the chi-square test or Fisher's exact test for categorical variables were used to compare the differences between the two groups. Statistical significance was set at $p < 0.05$. SPSS v.21 (IBM Co., Armonk, NY, USA) was used for statistical analysis.

3. Results

3.1. Comparison of VAS scores and ODI between ATP and MI-TLIF groups

In this study, all basic patient data are presented in Table 1. To explore the effect of the two groups on pain relief, the VAS scores were compared at the 2nd, 4th, and 12th weeks after surgery (Figure 3). The VAS scores in ATP group were 0.4 ± 1.0, 0.1 ± 0.4, and 0.0 ± 0.0 after operation. In addition, the VAS scores in MI-TLIF group were 3.3 ± 1.0, 1.7 ± 0.8, and 0.9 ± 1.6 after operation. The ATP group had significantly reduced VAS scores at 2, 4 and 12 weeks after operation. The ODI scores were compared at the 2nd, 4th, and 12th weeks after surgery. The ODI scores in the ATP group were 1.1 ± 3.0, 0.3 ± 1.0, and 0.1 ± 0.4 after operation. Then, the ODI scores in MI-TLIF group were 12.9 ± 4.8, 3.4 ± 2.0, and 0.9 ± 1.6 after operation. At that time, there was also a significant difference in the ODI scores at 2, 4 and 12 weeks after operation (Figure 4).

3.2. Intraoperative safety between ATP and MI-TLIF groups

To investigate intraoperative safety, blood loss (Figure 5), operation time (Figure 6), intraoperative nerve injury, and vessel trauma were recorded and compared between groups of patients. There was no intraoperative nerve injury, no CSF leakage, no neurological deficits, no infection and no vessel injuries reported. The amount of blood loss was 44 ± 35 ml in the ATP group and 291.1 ± 135.4 ml in the MI-TLIF group. A significantly lower amount of blood loss was reported in the ATP group. The two kinds of operations for patients are safe and effective for lumbar degenerative disease in this study, and similar results have been described in some studies.[15,16]

3.3. Fusion rate between ATP and MI-TLIF groups

Fusion status was evaluated at 12 months using a CT scan. Using the Bridwell fusion grading system, grade 1 was viewed as a fusion status. Twelve months after the operation, the fusion rates in the ATP and MI-TLIF groups were 90% (18/20) and 72% (13/18), respectively. The ATP group had a faster fusion time than the MI-TLIF group. Guang-Xun et al. found similar results.[17]

4. Discussion

In the present study, we aimed to investigate the difference in outcomes between patients who underwent ATP vs. MI-TLIF. Patients in the ATP group showed better pain relief, higher function level according to ODI scores, less blood loss, and faster fusion than those in the MI-TLIF group. The results of VAS and ODI scores could explain why the patients in the ATP group returned to daily activities faster than those in the MI-TLIF group. Specifically, the ATP approach could offer greater correction of sagittal balance over open and MI-TLIF procedures, mainly regarding segmental lordosis, lumbar lordosis, and pain relief.[18]

The advantages of the ATP approach include its ability to facilitate minimally invasive surgery with rapid postoperative mobilization. In addition, the ATP approach allows for aggressive deformity correction and high fusion rates with comprehensive disc space clearance.[4,12] However, the potential risks associated with the ATP approach include sympathetic dysfunction and vascular injury.[15,19,20]

The better pain relief in the ATP group might be due to several

Table 1
Summary of patient characteristics and results.

Characteristic	ATP (n = 20)	MI-TLIF (n = 18)	*p*-value
Sex			0.299
M	10 (50%)	6 (33%)	
F	10 (50%)	12 (66%)	
Mean age (yrs)	57.3 ± 11.6	66.1 ± 13.4	0.036
Level			
L2/3	1		
L3/4	2		
L4/5	17	12	
L5/S1		6	
Type			
Spondylolisthesis	14	16	
Recurrent HIVD	5		
Lumbar stenosis	1	2	
VAS			
Pre-op	7.2 ± 1.0	7.6 ± 0.9	0.1
Post-op 2w	0.4 ± 1.0	3.3 ± 1.0	< 0.01
Post-op 4w	0.1 ± 0.4	1.7 ± 0.8	< 0.01
Post-op 12w	0.0 ± 0.0	0.6 ± 0.9	< 0.01
ODI (%)			
Pre-op	50.9 ± 6.1	51.9 ± 4.6	0.3
Post-op 2w	1.1 ± 3.0	12.9 ± 4.8	< 0.01
Post-op 4w	0.3 ± 1.0	3.4 ± 2.0	< 0.01
Post-op 12w	0.1 ± 0.4	0.9 ± 1.6	< 0.05
Fusion rate	18/20 (90%)	13/18 (72%)	0.222
Blood loss (mL)	44.3 ± 35.6	291.1 ± 135.4	< 0.01
Operation time (min)	204.5 ± 29.0	141.4 ± 35.8	< 0.01

ATP: anterior to psoas, HIVD: herniated intervertebral disc, MI-TLIF: minimally invasive transforaminal lumbar interbody fusion, ODI: Oswestry Disability Index, VAS: visual analogue scale.

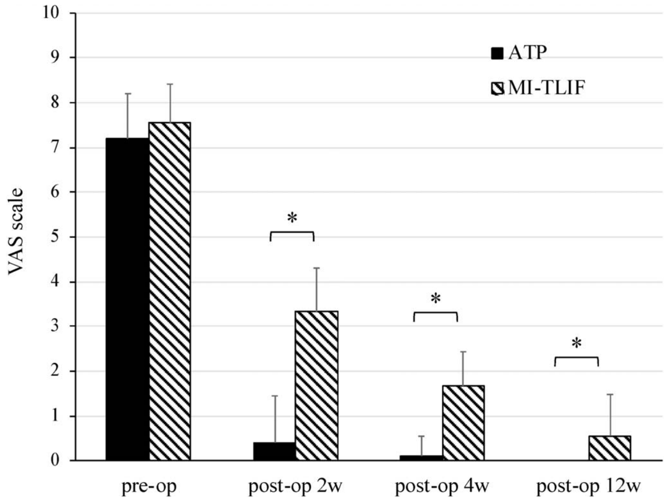

Figure 3. The change in visual analog scale (VAS) scores pre- and post-operation. The data were recorded at the 2nd, 4th, and 12th week after operation. The change of VAS scale between the ATP and MI-TLIF groups is significant. * $p < 0.05$ (by Student's t-test).

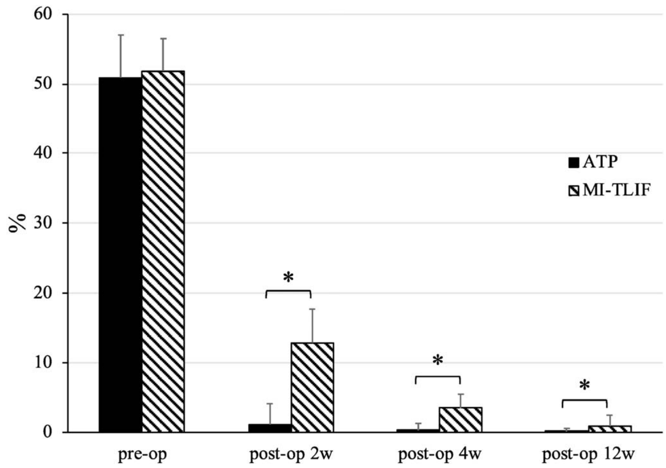

Figure 4. The Oswestry Disability Index (ODI) results from pre- and post-operation. The data were recorded at the 2nd, 4th, and 12th week after operation. The change of ODI between ATP and MI-TLIF groups is significant. * $p < 0.05$ (by Student's t-test).

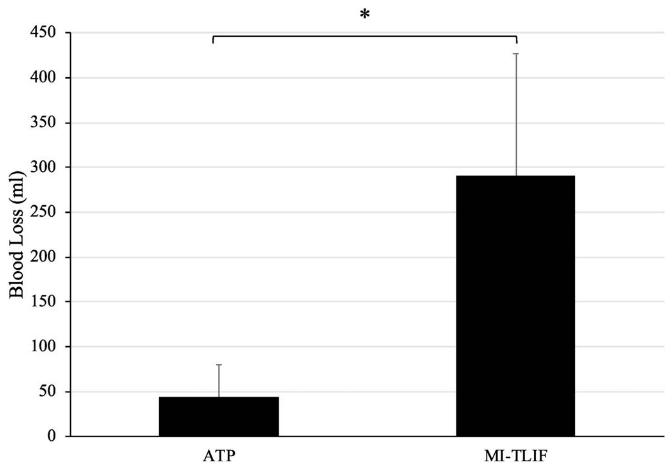

Figure 5. Amount of blood loss during operation. The amount of blood loss in the ATP approach is significantly less than in the MI-TLIF approach. * $p < 0.05$ (by Student's t-test).

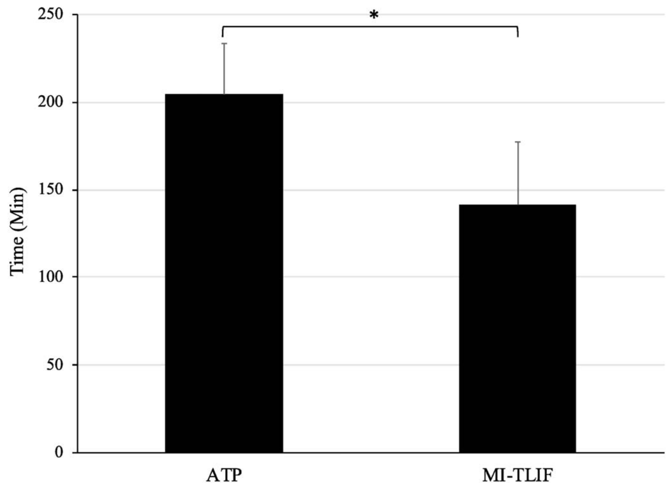

Figure 6. Operation time (minutes). The operation time in the MI-TLIF group is significantly less than in the ATP group. * $p < 0.05$ (by Student's t-test).

reasons. First, ATP could provide better sagittal balance than open and MI-TLIF.[18,21] Second, some surgeons have proposed that this advantage may be attributed to the better protection of the lumbar fascia and paravertebral muscles in ATP.[22] Therefore, it is not surprising to see a significant difference in ODI scores, where the patients who underwent the ATP approach were able to return to daily activities faster than the patients who underwent MI-TLIF. The advantages of the TLIF approach include relatively easier access to the posterior structures that contain the lamina, ligamentum flavum, and facet joints. However, TLIF associated with significant paraspinal iatrogenic injury and prolonged muscle retraction is a notable problem. As a result, the problem of coronal imbalance and lordosis would become a significant challenge in undertaking TLIF.[23]

Song et al. (2015) clearly indicated that the ATP approach for lumbar interbody fusion with internal fixation provided the best biomechanical stability in spines.[24] It is expected that this would lead to better outcomes in terms of pain relief. Another study released in 2019 described that the fusion rate was more than 90% in post-operation follow-up conducted at 18 months.[25] A related study from 2018 clearly mentions that the fusion of the ATP approach has greater performance than the fusion of MI-TLIF 6 months postoperatively.[17] This evidence supports the conclusion that the ATP approach provides better patient outcomes according to VAS and ODI scores.

The present study showed that there was less blood loss in patients undergoing ATP, similar to previous results.[15,17] In this study, the greatest amount of blood loss was due to the muscle split and internal fixation of the CBT screws which suggests that the midline approach and tapping of the screw holes causes muscle and bone bleeding. Viewing the operation course of ATP and MI-TLIF groups, the operation time of the ATP group was significantly longer than that of the MI-TLIF group. There could be several possible reasons. First, to identify and preserve the endplate of the vertebral body by a true lateral decubitus position of the lumbar spine is important in the ATP approach. Some patients in the ATP group had mild to moderate scoliosis, which could have increased the posture preparation time. Second, the patients have been changed from the lateral decubitus position to the prone position for partial laminectomy that are useful for severe lumbar stenosis as seen in other studies.[26–28]

There are limitations of the study to consider. First, it was a retrospective study with a relatively small sample size. Furthermore, patients could choose the surgical technique after the doctor's explanation. This might be the reason why there was a significant difference in mean age between the two groups.

5. Conclusion

Both ATP and MI-TLIF approaches are effective and safe for patients. The patients who underwent ATP showed faster recovery than those in the MI-TLIF group according to the VAS and ODI scores. In addition, the ATP group showed less blood loss and seemed to be faster fusion status than the MI-TLIF group. Under CBT fixation, direct and indirect decompressions could be integrated by the ATP approach combined with partial laminectomy. These results would enhance the surgeon's confidence in selecting the ATP approach for patients.

Acknowledgement

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