



Technical Note

A novel computer algorithm allows for volumetric and cross-sectional area analysis of indirect decompression following transposas lumbar arthrodesis despite variations in MRI technique



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ABSTRACT

Many patients present for neurosurgical spine evaluation with MRI studies conducted at facilities outside of the treating medical center. These images often vary widely in technique, for example, variation in slice thickness, number of slices, and gantry angle. While these images may be sufficient in conjunction with a physical exam to make surgical evaluations, we have found they are often incapable of being used for objective post-operative volumetric comparisons. In order to overcome this, we created a computer program that compensates for these variations in MRI technique. For this study, we examined patients who had undergone outside MRI pre-operatively and were deemed appropriate for a lateral retroperitoneal transposas lumbar interbody arthrodesis procedure. Volumetric analysis was performed on sagittal and axial T2-weighted pre- and post-operative MRI. The percentage change of central canal volume and foraminal area was calculated for each level. The authors identified five levels with MRI sufficient for volumetric analysis and eight levels (16 foramina) sufficient for foraminal cross-sectional analysis. Through use of our computer algorithm, average central canal volume and foraminal cross-sectional area was calculated to increase by 32.8% and 67.6% respectively following the procedure. These results are consistent with previous study findings and support the idea that restoration of the anterior column via a lateral approach can result in significant indirect decompression of the neural elements. Additionally, the novel algorithm created and used for this study suggests that it can achieve quick measurement and comparison of MRI studies despite variations in pre- and post-operative technique.

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1. Introduction

Many patients present for neurosurgical spine evaluation from the community setting with MRI studies conducted at facilities outside of the treating medical center. These images often vary widely in technique, including variation in slice thickness, number of slices and gantry angle. While these images may be sufficient in conjunction with a physical exam to make surgical evaluations, we have found they are often not useful for objective post-operative comparison for the purpose of volumetric measurements. Ultimately, this may preclude using these surgical results in some studies and therefore lose information for analysis. While this factor would be prevented by repeating the outside images at the treating medical center, this may subject patients to unnecessary tests and costs. In order to overcome this, we created a computer program that allows for these variations in MRI technique.

The lateral retroperitoneal transposas approach is a minimally invasive technique for lumbar arthrodesis that has been

increasingly utilized for the treatment of various spinal disorders. The procedure utilizes a corridor through the retroperitoneal space and the psoas muscle to access the lateral aspect of the lumbar spine. The benefits of this approach include the ability to spare paraspinal musculature dissection and stabilizing ligamentous disruption required in posterior approaches, and reduced operative time, blood loss, post-operative pain and hospital length of stay.^{1,2} Additionally, this exposure allows placement of a substantially larger interbody cage, which may decrease subsidence and increase fusion rates.³ The ability to maximally restore disc height may also provide significant ligamentotaxis, thereby indirectly decompressing the neural elements.^{4,5}

In the setting of lumbar stenosis, soft tissue or bony compression can lead to neurogenic claudication or radicular symptoms, depending on the location of the stenosis which may cause central, lateral recess or foraminal compression. Direct decompression of neural elements is the goal of treatment; however, decompression alone in patients with malalignment has been shown to be less effective than decompression and stabilization.⁶ The lateral retroperitoneal transposas allows placement of a large interbody cage and indirectly decompress the neural elements addressing both

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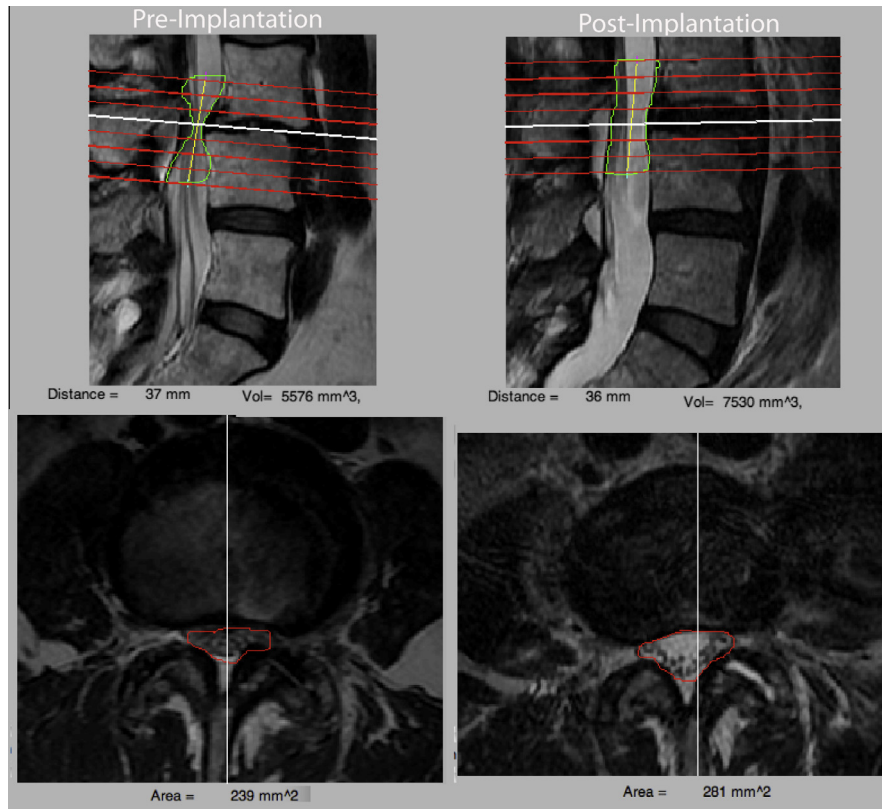


Fig. 1. (Top) Sagittal T2-weighted non-contrast MRI of the lumbar spine showing the pre-operative (left) and post-operative (right) central canal. The average volume of the central canal increased by 32.8%. (Bottom) Axial T2-weighted non-contrast MRI of the lumbar spine showing cross-sectional area at the slice of the greatest stenosis pre-operatively (left) and post-operatively (right). The area of the central canal was found to increase by an average of 79.5%. Vol = volume.

instability and neural compression, including in spondylolisthesis or adult degenerative scoliosis with significant loss of disc height with stenosis.^{7–9}

In this study, we performed a volumetric and cross-sectional area analysis on the pre- and post-operative (at least 3 months) lumbar MRI performed using different techniques for patients who underwent a lateral retroperitoneal transpsoas procedure. The aim was to quantify the percentage of increased central canal volume and cross-sectional foraminal area achieved by indirect decompression. The algorithm used is unique and was created to compare MRI of the spine performed with different techniques, including slice thickness, number of slices, and differences in gantry angle.

2. Materials and methods

The Institutional Review Board at Stanford University Medical Center approved the study protocol. We retrospectively reviewed all the lateral retroperitoneal transpsoas lumbar interbody arthrodesis procedures using a 26 mm cage performed by the senior author at Stanford University Medical Center from 2009 to 2013. Appropriate pre- and post-operative (at least 3 months) MRI were identified. Volumetric and cross-sectional analysis using a novel computer algorithm was performed on sagittal and axial pre- and post-operative T2-weighted images. Percentage volume change was calculated for each of five levels that fit the necessary pre- and post-operative MRI requirements (Fig. 1). Area analysis using the same novel algorithm was performed on sagittal T2-weighted images pre- and post-operatively for eight levels (16 foramina) that met the necessary requirements. The percentage of cross-sectional area change was calculated for each foramen

(Fig. 2). All patients had been diagnosed with lumbar stenosis secondary to degenerative disc disease or Grade 1 spondylolisthesis.

The computer algorithm created uses a variation of Green's theorem. The calculations are made by creating a volumetric total through the summation of multiple smaller volumes extrapolated by manual cross-sectional area measurements and known slice thickness values. The calculations are commenced at clear anatomical points and are not greatly affected by small variations in gantry angle as the small variations are minimized by averaging and nearly symmetric negative changes in the z plane over the course of the calculations. Variations in number of slices between pre- and post-operative MRI scans do not affect the calculation as they are accounted for by the smaller volume calculations.

3. Results

3.1. Volumetric analysis

Using a volumetric analysis algorithm, five patient pre- and post-operative lumbar spine MRI were evaluated following a lateral retroperitoneal transpsoas lumbar interbody arthrodesis procedure using 26 mm long interbody cages. Five levels were available for review. The average volume of the central canal increased by 32.8%. Cross-sectional area at the slice of the greatest stenosis was found to increase by an average of 79.5% (Fig. 1, bottom panels).

3.2. Cross-sectional analysis

Using a cross-sectional contour analysis algorithm, six lumbar spine MRI were evaluated pre- and post-operatively following a lateral retroperitoneal transpsoas lumbar interbody arthrodesis

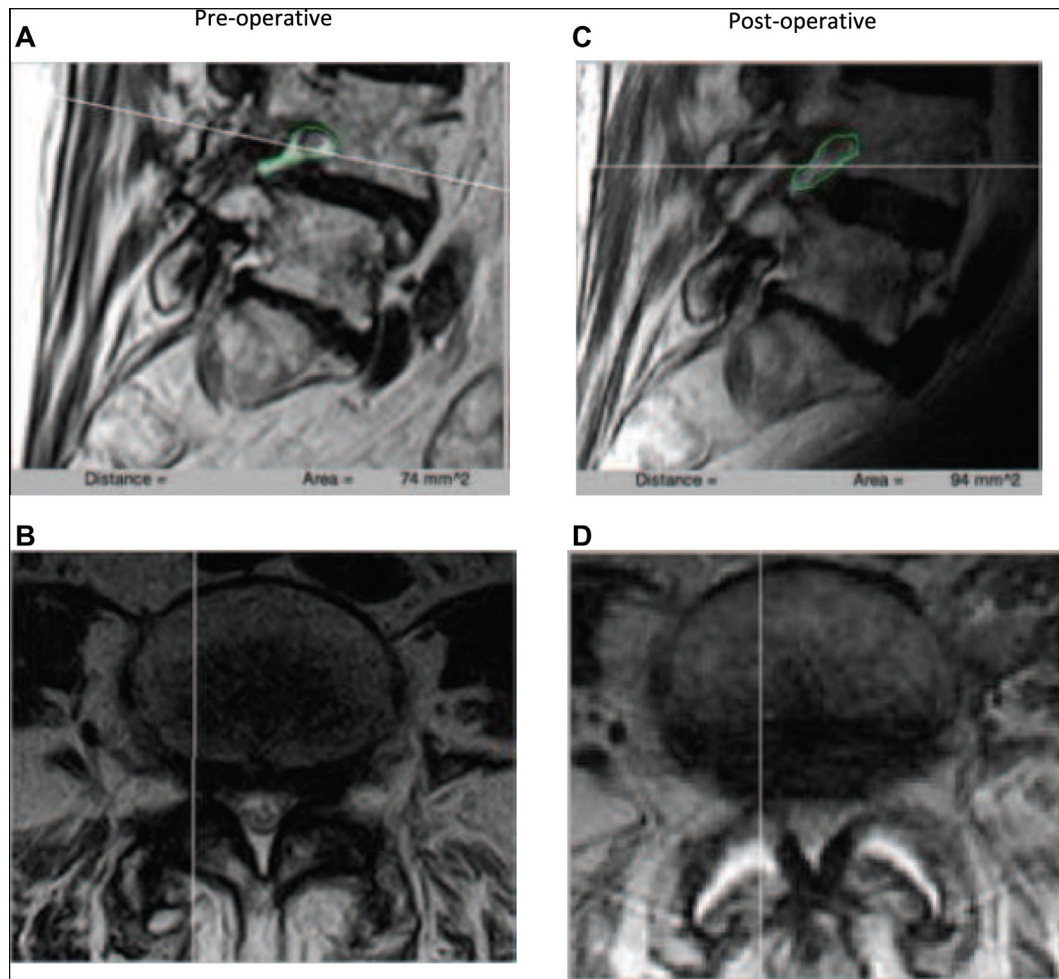


Fig. 2. (A, C) Sagittal and (B, D) axial T2-weighted non-contrast MRI of the lumbar spine showing the average increase in foraminal area from pre-operative (left) to post-operative (right) was 67.6%.

procedure. During the procedure, patients had 26 mm long interbody cages placed via a lateral approach without posterior decompression. All interbody grafts were found to be in good position and placed in the anterior half of the intervertebral space. Eight levels (16 foramina) were available for review. The average increase in foraminal area was found to be 67.6% post-operatively.

4. Discussion

With the rising costs of health care and medical procedures, many patients are now responsible for the remainder of hospital bills not covered by their insurance. Additionally, many insurance companies are now limiting the number of MRI scans they will approve. Yet, despite the difficulty with reimbursement for exams such as MRI, there continues to be a need for continued research into novel procedures and patient outcome. All of these factors suggest the need for new modalities that allow data collection and continued learning even under non-ideal circumstances.

Studies have been published in the literature supporting interbody arthrodesis for indirect decompression of spondylolisthesis with spinal stenosis.^{10,11} Our study is consistent with these reports, in that we demonstrated indirect decompression using lateral interbody fusion in lumbar degenerative disorders. The ability to place large interbody cages through the lateral retroperitoneal transpsoas approach adds significant stability, as these cages cross both sides of the apophyseal ring.¹² The approach allows for place-

ment of these wider and taller cages and avoidance of the corresponding nerve roots. The distraction and restoration of disc height from these cages, through ligamentotaxis, is also able to provide spinal deformity correction.⁷ This, along with indirect decompression the neural elements, makes the lateral approach an attractive option for lumbar fusion.

This study showed our experience with lateral interbody decompression to be consistent with the literature.^{13,14} More importantly, our data were able to be collected and analyzed from MRI studies performed under varying conditions and on different MRI machines, through use of our novel computer algorithm. These results are promising in that algorithms such as this one may help increase the breadth of research and knowledge even in the face of more limited healthcare funds.

5. Conclusions

Stand-alone transpsoas lumbar interbody grafts were found to reliably decompress the central canal and neural foramina, and indirectly expand the thecal sac adjacent to the operated segment in this small series. Volumetric and area analysis via an algorithm designed by our team allowed for evaluation and comparison of pre- and post-operative MRI despite variations in MRI technique and parameters. The only limitations of this technique appear to be drastic variations in slice gantry angle.

Conflict of interest/disclosure

The authors declare that they have no financial or other conflicts of interest in relation to this research and its publication.

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