Early experience with endoscopic revision of lumbar spinal fusions

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Approximately half a million spinal fusion procedures are performed annually in the US. It is estimated that up to one-third of arthrodesis constructs require revision surgeries. In this study the authors present endoscopic treatment strategies targeting 3 types of complications following arthrodesis surgery: 1) adjacent-level foraminal stenosis; 2) foraminal stenosis at an arthrodesis segment; and 3) stenosis caused by a displaced interbody cage.

A retrospective chart review of 11 patients with a mean age of 68 ± 15 years was performed (continuous variables are shown as the mean $\pm$ SEM). All patients had a history of lumbar arthrodesis surgery and suffered from unilateral radiculopathy. Endoscopic revision surgeries were done as outpatient procedures, and there were no intraoperative or perioperative complications. The cohort included 3 patients with foraminal stenosis at the level of previous arthrodesis. They presented with unilateral radicular leg pain (visual analog scale [VAS] score: 7.3 ± 2.1) and were severely disabled, as evidenced by an Oswestry Disability Index (ODI) of 46 ± 4.9 . Transforaminal endoscopic foraminotomies were performed, and at a mean follow-up time of 9.0 ± 2.5 months VAS was reduced by an average of 6.3. The cohort also includes 7 patients suffering unilateral radiculopathy due to adjacent-level foraminal stenosis. Preoperative VAS for leg pain of the symptomatic side was 6.0 ± 1.6 , VAS for back pain was 5.2 ± 1.7 , and ODI was 40 ± 6.33 . Endoscopic decompression led to reduction of the ipsilateral leg VAS score by an average of 5, resulting in leg pain of 1 ± 0.5 at an average of 8 months of follow-up. The severity of back pain remained stable (VAS 4.2 ± 1.4). Two of these patients required revision surgery for recurrent symptoms. Finally, this study includes 1 patient who presented with weakness and pain due to retropulsion of an L5/S1 interbody spacer. The patient underwent an endoscopic interlaminar approach with partial resection of the interbody cage, which resulted in complete resolution of her radicular symptoms.

Endoscopic surgery may be a useful adjunct for management of certain arthrodesis-related complications. Endoscopic foraminal decompression of previously fused segments and resection of displaced interbody cages appears to have excellent outcomes, whereas decompression of adjacent segments remains challenging and requires further investigation.

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SPINAL arthrodesis surgery is commonly performed in patients with trauma, degenerative spinal disease, neoplasms, or infections in whom conservative measures such as physical therapy, chiropractic interventions, and pain management fail. The goal of spinal fusion surgery is to stabilize or reapproximate normal alignment of spinal anatomy. Each year, approximately half a million patients undergo spinal arthrodesis procedures in the US. The rates of fusion procedures have rapidly increased in the US, rising from 174,223 procedures in 1998

to 413,171 in 2008.¹⁰ The main driver of increased use of spine surgery may be attributed to the rapid aging of our population. Patients 65 years or older are the fastest-growing age group in the US, and currently represent 17% of our total population. Thus, demand for therapeutic interventions targeting low-back pain and neck pain has risen dramatically. Between 1999 and 2009, the number of initial physical therapy evaluations increased by 1.4 million and chiropractic interventions increased by 8.3 million.³ Comparatively the increase of spinal procedures has been

ABBREVIATIONS ODI = Oswestry Disability Index; PEEK = polyetheretherketone; TLIF = transforaminal lumbar interbody fusion; VAS = visual analog scale.

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modest; however, there is a strong demand for surgical interventions associated with less perioperative morbidity, decreased stress on adjacent spinal segments, and higher cost-effectiveness.

Clinical outcomes following spinal arthrodesis procedures are constantly improving, and surgeons are growing more adept at mitigating serious complications.¹⁰ However, even after successful fusion operations, additional surgical interventions are often required in the long term. In patients undergoing posterior lumbar fusions for spondylolisthesis, up to 29% were found to require reoperation.^{1,9} Moreover, up to 50% of patients have new or residual radiculopathy following fusion, due to pseudarthrosis, exacerbation of spondylolisthesis, and adjacent-segment disease.⁹ Reoperation in this context often requires revision or extension of the instrumented fusion.

The use of endoscopic techniques for spine surgeries is increasing. Endoscope-assisted lumbar discectomy was first described in 1997 by Foley et al.,⁷ and has since been established as a viable method of treating lumbar spinal stenosis. In addition, fully endoscopic foraminotomy has been developed as a minimally invasive approach for effectively decompressing stenotic lumbar foramina, and has been shown to result in good clinical outcomes.^{2,8,12} Cadaveric studies have been undertaken and have further demonstrated the anatomical effectiveness of endoscopic foraminotomies in achieving foraminal decompression.⁶ The purpose of this study was to investigate the utility of endoscopic foraminotomy for highly targeted revision surgery in selected patients with persistent radiculopathy following lumbar fusion surgery.

Methods

Patient Population

Our prospective database of 80 endoscopic spine procedures was screened for patients who had undergone previous lumbar arthrodesis surgeries. All patients who underwent endoscopic decompressive procedures performed within the levels of the previous arthrodesis procedures or at an adjacent level were included in the current series. Thus, our report includes a total of 11 patients with unilateral lower-extremity radiculopathy following lumbar arthrodesis surgery. Patient demographic data, operative details, clinical outcomes, complications, and radiographic imaging were reviewed. Outcomes were measured using the visual analog scale (VAS) and Oswestry Disability Index (ODI) scores. Seven patients suffered from unilateral symptomatic foraminal stenosis adjacent to an existing fusion construct, 3 patients presented with symptomatic foraminal stenosis at the level of an existing arthrodesis surgery, and 1 patient had radiculopathy due to a displaced interbody cage.

Statistical Analysis

Continuous variables are shown as the mean $\pm$ SEM.

Results

The current report includes a cohort of 11 patients, which consists of 5 women and 6 men. The mean age was

68 $\pm$ 15 years. All patients had undergone previous lumbar arthrodesis surgery. Approximately half of these patients ($n = 6$) had 1-level fusion surgeries, and the remaining had either 2-level ($n = 4$) or 3-level ($n = 1$) procedures. All endoscopic revision surgeries were done as outpatient procedures. There were no intraoperative or perioperative complications.

Foraminal Decompression at Arthrodesis Level

In this study, 3 patients had symptomatic foraminal stenosis at the level of their previous arthrodesis that was causing radiculopathy. Preoperative imaging revealed that all 3 patients had achieved successful arthrodesis at the affected segment; however, unilateral collapse of the intervertebral space led to foraminal stenosis (Fig. 1). Thus, foraminal height was on average 9.2 $\pm$ 1.6 mm on the symptomatic side compared with 13.4 $\pm$ 0.8 mm on the contralateral side. The preoperative VAS score on the side of the radicular pain was 7.3 $\pm$ 2.1. These patients had only minimal complaints of contralateral leg pain or back pain. However, a preoperative ODI of 46 $\pm$ 4.9 indicated that these patients were severely disabled by their symptoms. All patients underwent endoscopic foraminotomies (Fig. 2). At a mean follow-up time of 9.0 $\pm$ 2.5 months, the average VAS score for leg pain on the symptomatic side was reduced by 6.33. Patients rated their leg pain on average as 1.0 $\pm$ 1.0. One patient had 4 weeks of transient postoperative paresthesias, which completely resolved.

Foraminal Decompression at an Adjacent Level

Seven patients suffered from adjacent-level unilateral symptomatic foraminal stenosis. Patients reported preoperative leg VAS of 6 $\pm$ 1.6 for the symptomatic side and 2.5 $\pm$ 1.3 for the contralateral side. In contrast to patients with foraminal stenosis within the fusion construct, patients with radicular symptoms at adjacent levels also had significant back pain (VAS 5.2 $\pm$ 1.7). These patients were severely disabled, as indicated by an ODI of 40 $\pm$ 6.3. Preoperative imaging revealed that the foraminal height was smaller on the symptomatic side (8.8 $\pm$ 0.8 mm) when

FIG. 1. A: Example of unilateral foraminal stenosis at arthrodesis segment. Preoperative coronal reconstruction of an arthrodesis segment with loss of intervertebral space height resulting in foraminal stenosis (asterisk). **B:** Sagittal T1-weighted MRI study depicts an additional foraminal disc bulge (arrow), which further aggravates foraminal stenosis.

FIG. 2. Endoscopic foraminotomy. **A:** During the initial phase of the foraminotomy the Kammin's triangle is exposed. Asterisk indicates the superior articulating process. The arrow points toward the foraminal disc protrusion. **B:** An articulating bur has been used to resect the anterior aspect of the superior articulating process, including the tip of the process (asterisk). The arrow depicts the foraminal disc protrusion. **C:** Following partial resection of the superior articulating process (asterisk) and resection of the foraminal disc, protrusion of perineural fat surrounding the exiting nerve root is noted (arrow).

compared with the nonsymptomatic side (14.5 ± 0.1 mm). Endoscopic decompression resulted in an average reduction of VAS by 5 for leg pain, resulting in a VAS of 1 ± 0.5 at an average of 8-month follow-up. The back pain VAS scores remained stable (4.2 ± 1.4). Two of the included patients required revision surgery for return of symptoms.

The first patient initially experienced complete relief of his preoperative leg pain. However, 6 months after the procedure he suffered recurrent symptoms due to a foraminal disc reherniation. Two months after a repeat endoscopic procedure, this patient was doing well. Another patient was pain free for 4 months before his symptoms recurred due to exacerbation of a segmental coronal deformity. He required a segmental stabilization performed via a far lateral approach. His radicular symptoms resolved and he is currently recovering from the procedure.

Decompression for Interbody Spacer Retropulsion

Finally, a 39-year-old woman who had undergone an L4–S1 transforaminal lumbar interbody fusion (TLIF) 9 years previously presented with right-sided posterolateral thigh and calf pain. The patient also had right-sided extensor hallucis longus weakness (3/5 strength on examination). Preoperative imaging revealed that the L5/S1 interbody spacer was displaced posteriorly. This caused severe lateral recess stenosis (Fig. 3A and 3B). The patient underwent an endoscopic interlaminar partial resection of the interbody cage (Fig. 3C–F), which resulted in complete recovery.

Discussion

The number of arthrodesis surgeries has increased substantially during the last 10 years in the US.¹⁰ Given the aging of our population, an increasing number of procedures are carried out in patients of advanced age and with multiple comorbidities, which have both been shown to be associated with higher complication rates.^{4,11} Moreover, complication rates appear to correlate positively with increased complexity of instrumentation.¹³ The number of patients requiring revision surgery with extension of fusion constructs approached 10% at 2 years in the Spine Patient Outcomes Research Trial (SPORT) findings, and 29% of all patients will need to undergo further fusion

surgery.^{1,9} This represents a large cohort of patients who often need additional fusion surgery, with significant associated morbidity. The challenge is compounded by the massive increase in the number of complex fusion opera-

FIG. 3. Example of dislodged hardware. **A:** A retropulsed polyetheretherketone (PEEK) TLIF cage leads to compression of the traversing S-1 nerve root (arrow). **B:** An axial CT image confirms the retropulsed cage. **C:** Intraoperative image reveals remaining S-1 lamina (asterisk) following partial hemilaminectomy. The traversing S-1 nerve root is exposed (arrow). **D:** The S-1 nerve root is retracted medially using the working channel. Approximately half of the retropulsed PEEK cage has been resected. **E:** Resection of the protruded PEEK cage is completed and the medial aspect of the cage is exposed (arrow). **F:** Postoperative CT scan confirms resection of the protruding cage.

tions being performed in the elderly, with an estimated 15-fold increase between 2002 and 2007.⁵ Revision surgery typically involves revision of instrumentation and/or extension of the fusion construct to additional levels.

In our current report we describe endoscopic revision as an alternative treatment strategy for selected patients who suffer from radiculopathy following arthrodesis surgery. Our results seem to indicate that highly targeted endoscopic decompression of nerve roots within a successful arthrodesis construct is feasible and may result in symptomatic relief. Our results for endoscopic decompression surgery within arthrodesis constructs mirror the results recently published by Telfeian.¹² In his study, endoscopic foraminotomy performed in 5 patients at the segment previously treated with arthrodesis surgery resulted in a reduction of VAS by 6. The reduction of pain found in the current study was very similar. Moreover, we present a case in which a traversing nerve root was decompressed by partial resection of a retropulsed TLIF cage that was performed using the interlaminar technique. Given the very narrow working corridor of less than 10 mm between the spinous process and the pedicle screw, in our hands other surgical techniques would have not permitted safe resection of the protruded cage underneath the traversing nerve root without removal of the instrumentation. Given that decompression was carried out in these patients within a solid fusion mass, we anticipate that these results will be durable. However, a larger number of patients and longer follow-up times are needed.

As expected, treatment of adjacent-segment foraminal stenosis was challenging. While patients experienced reduction of their radicular pain, 2 out of 7 patients required further surgical interventions within our limited follow-up interval. One patient suffered from a recurrent foraminal disc herniation which required revision endoscopic discectomy. The other patient experienced recurrent radiculopathy due to progressive unilateral foraminal collapse following endoscopic foraminotomy; this patient required subsequent arthrodesis surgery. It is possible that segmental instability might have contributed to this rapid foraminal collapse following decompression. His preoperative flexion and extension lumbar radiographs displayed extensive segmental motion (segmental lordosis changed 12.8° between flexion and extension). Further studies should address whether certain static or dynamic radiographic parameters might be associated with a high failure rate following decompressive procedures for adjacent foramina. Moreover, longer follow-up times are needed to better define the durability of this intervention. It seems very likely that certain patients might be better candidates for immediate arthrodesis surgery.

Conclusions

As the number of complex fusion surgeries increases, especially in elderly patients with multiple comorbidities, there is a great need to develop new minimally invasive revision strategies. In the current report we propose that endoscopic decompression surgery within and adjacent to the segment of spinal arthrodesis may alleviate radicu-

lar symptoms in selected patients. We acknowledge that the results of the current study are limited due to a short follow-up time and a small patient cohort. However, given that the invasiveness and perioperative morbidity of the presented technique is dramatically less compared with typical revision surgeries, this technique warrants further investigation. Moreover, given the high failure rate of adjacent-level decompression, further studies of larger patient cohorts with long-term follow-up are needed to better define appropriate candidates for such a procedure. Nevertheless, our preliminary results suggest that endoscopic decompression might be a useful strategy for selected patients with unilateral radiculopathy following arthrodesis surgery.

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Disclosures

Dr. Wang is a consultant for DePuy Spine, Aesculap Spine, joimax, and K2M. He is a patent holder with DePuy Spine. Dr. Hofstetter is a consultant for Johnson & Johnson and for InVivo Therapeutics.

Author Contributions

Conception and design: Hofstetter, McGrath, Madhavan, Wang. Acquisition of data: McGrath, Madhavan, Chieng, Wang. Analysis and interpretation of data: McGrath, Chieng. Drafting the article: McGrath. Critically revising the article: McGrath. Study supervision: Hofstetter, Wang.

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