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Original Article

Minimally invasive spine surgery in the pediatric and adolescent population: A case series

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Abstract

Background: There is scant literature evaluating the indications, techniques, and outcomes of minimally invasive spine (MIS) surgery undertaken for pediatric and adolescent spine pathology. Our study attempts to evaluate the safe and effective use of MIS techniques in pediatric and adolescent patients and to appreciate the technical nuances of MIS surgery for this age group.

Methods: Consecutive pediatric and adolescent patients undergoing elective MIS lumbar procedures, from 2008 to 2016, were retrospectively analyzed from the practice of a single fellowship-trained academic spinal neurosurgeon. Information was retrieved regarding procedure and disease pathology. Descriptive data was obtained including age, sex, body mass index (BMI), insurance coverage, smoking status, and co-morbidities. Outcome measures were recorded including intraoperative complications, revision surgery, and return-to-function.

Results: Sixteen patients underwent 17 surgeries. The median BMI was 29.2 (range, 20.8–41.5). Age ranged from 12 to 19 years. Nearly 20% of the patients in our series were smokers. Most patients underwent discectomy, with L5-S1 being the most common level. One patient underwent direct pars defect repair and another underwent recurrent discectomy. More than 90% of the patients were complication-free at follow-up period of 6 months. One patient had a recurrent disc herniation and another had a superficial wound infection. Overall, 82.4% patients enjoyed full return to sports such as weight lifting, gymnastics, and contact sports. One patient required pain management to help alleviate ongoing pain. Another patient required a course of outpatient rehabilitation to help with a "foot drop."

Conclusion: Our series illustrates the effective application of MIS techniques among carefully selected pediatric patients. Emphasis is on using a smaller (16 mm) tubular retractor and causing minimal disruption of paraspinal osseo-tendinous

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structures. MIS techniques can be successfully applied to the pediatric and adolescent age group.

Key Words: Adolescent spine surgery, direct pars repair, minimally invasive spine surgery, pediatric discectomy, pediatric laminectomy, pediatric spine surgery

INTRODUCTION

With the incidence of spinal pathology on the rise in the United States, spinal surgery options have also continued to diversify in both technique and application. In particular, minimally invasive spine (MIS) surgery has become increasingly popular for both decompression and instrumentation throughout the lumbar, thoracic, and cervical spine.[10] Advantages to minimally invasive spine surgery are readily apparent including smaller incisions, shorter hospital stays, less disruption of surrounding tissue, and reduced infection rates.[2,6]

MIS surgery was designed around, and has historically been applied to, the adult patient population.[6,10] There is a dearth of literature regarding the application of minimally invasive techniques to spinal pathology in the pediatric population with the exception of proposed application to scoliosis correction.[10,12,13] However, due to its minimal tissue destruction and targeted decompression, MIS shows great promise in appropriately selected pediatric patient cohorts.[4] Here, we illustrate the patient characteristics, operative technique, and surgical outcomes for minimally invasive lumbar spine surgery at our institution.

MATERIALS AND METHODS

Consecutive pediatrics and adolescent patients undergoing elective minimally invasive lumbar spine procedures were retrospectively analyzed from a single fellowship trained academic spinal neurosurgeon with privileges at both a private as well as a teaching hospital.

Information was retrieved regarding minimally lumbar invasive spinal procedure and disease pathology. Descriptive data was obtained regarding age, sex, height, weight, body mass index (BMI), insurance coverage, smoking status, or significant co-morbidities. Age range considered was any patient less than 19 years of age. The incorporation of patients up to the age of 19 was due to the fact that their clinical entity, conservative management, and work-up process for pathology likely began in the pediatric spectrum.

Years of surgeon experience and hospital practice setting (private versus academic) were abstracted. Outcome measures such as intraoperative complications, revision surgery, pain control issues, and return-to-function and physical activity were analyzed. A standard postoperative course of pain medication was determined as six weeks of by mouth narcotics prescribed by the neurosurgeon. Additional pain control was defined as any additional pain medication or pain-related issues treated by a primary care provider or neurosurgeon. Pain management indicates the need for pain management to become involved in the patient's long-term pain control.

Data was analyzed using appropriate statistical testing. Mean was considered with standard deviation. The use of range for age despite a mean presentation was intentionally used to show a better indication of spread and outliers in a smaller cohort.

Surgical technique

The procedure for pediatric discectomy is identical to the adult procedure, albeit with several caveats. First and foremost, emphasis is placed on minimizing muscle dissection and maintaining normal spine architecture. As such, a 16-mm tube is used as opposed to the typical 18-mm or 22-mm tube. The patient is placed prone on the Jackson spine table. Midline is marked with palpation of the spinous processes. A second line is marked 1.5 cm to the lateral midline for the corresponding side. The patient is prepped and draped in a standard sterile fashion. A 22-gauge spinal needle is used to localize the proper level on lateral fluoroscopy as well as to ensure a trajectory parallel to the disc space. A 22-mm incision is then made with sequential dilation using only the last two dilators to aide in subperiosteal dissection.

A proper 16-mm long tube is then inserted and fixated. Subsequently, a combination of monopolar and bipolar cautery is used to remove any additional muscle on the field. A high-speed drill and a combination of Kerrison rongeurs are used to free the bone and ligament from the nerve root. The disc is palpated and the nerve root is retracted safely. The disc is excised with a knife and pituitary rongeur with a partial annulotomy aided by an up-going and down-going curette. The nerve root is then palpated in all directions using a Woodson dissector. Hemostasis is achieved and the tube removed with direct visualization of bipolar coagulation of any muscle bleeding. The skin is closed with a deep fascia suture and several inverted 2-0 vicryl sutures. A skin glue is also used. Patients are generally discharged home the same day.

RESULTS

Descriptive data is shown in Table 1. Sixteen individual patients underwent 17 MIS procedures. The split between male and female was relatively even with 56.3% of the patients being male. An average number of patients in our series were obese with a BMI of 29.4 with a standard deviation of 6.5 (range, 20.8–41.5; median BMI, 29.2). Ages ranged 12–19 with 16 being the mode with six patients presenting at that age. Most patients underwent discectomy with L5-S1 being the most common level.

Table 1: Descriptive data for minimally invasive spine surgery

Variable	Response	Data
Number of patients	16 patients	
	17 surgeries	
Type of procedure	MIS discectomy	82.4% (14/17)
	MIS laminectomy	5.9% (1/17)
	MIS Recurrent discectomy	5.9% (1/17)
	Direct pars repair	5.9% (1/17)
Sex	Male	56.3% (9/16)
	Female	43.8% (7/16)
Age	Mean	16.75 years
	Range	12-19 years
Body mass index	Mean	29.4
	SD (95% CI)	6.522 (25.882 to 33.105)
Pathology	L4-5 disc herniation	41.2% (7/17)
	L5-S1 disc herniation	52.9% (9/17)
	L5-S1 recurrent disc herniation	5.9% (1/17)
	L5 pars defect	5.9% (1/17)
Smoking	Yes	18.8% (3/16)
	No	81.3% (13/16)
Insurance coverage	Medicaid	43.8% (7/16)
	Commercial	43.8% (7/16)
	None	12.5% (2/16)

MIS: Minimally invasive spine, SD: Standard deviation, CI: Confidence interval

Table 2: Clinical outcome and complications of minimally invasive lumbar surgery in the pediatric and adolescent population

Variable	Response at 6-month follow-up	Data
Complications	No complication	88.2% (15/17)
	Superficial wound infection	5.9% (1/17)
	Revision surgery for recurrent discectomy	5.9% (1/17)
Pain control	Standard postoperative medication	76.5% (13/17)
	Additional pain control	17.6% (3/17)
	Pain management	5.9% (1/17)
Functional outcome	Return to full activity/sports	82.4% (14/17)
	Functional outcome/sport	11.8% (2/17)
	limitation Rehabilitation (outpatient)	5.9% (1/17)

One patient had a direct pars defect repair and another had a recurrent discectomy.

Nearly 20% of the patients in our series were smokers including two patients under the age of 18. Three patients (18.8%) were on mood-related medications at the time of their surgery; two of those patients were on antidepressants.

Data involving operative outcomes is shown in Table 2. The average follow-up period at which patients were seen in the clinic was 6 months. Nearly 90% of patients did not suffer a complication. One patient had a recurrent disc herniation and one patient had a superficial wound infection. No deep infections occurred. Overall, 82.4% (14/17) patients enjoyed a full return to sports such as weight lifting, gymnastics, or contact sports. One patient required pain management to help alleviate ongoing pain. One patient required a course of outpatient rehab to help with a foot drop pathology.

DISCUSSION

The rapid evolution of MIS surgery in the past decade has laid the ground for its applications in newer and more complex spinal pathologies.[7] Essentially, MIS defers from traditional spine surgery by laying stress on decreasing muscle crush injuries during retraction and avoiding the disruption of osseo-tendinous complex of paraspinal muscles.[4] By emphasizing on the above strategies, MIS aims to achieve the desired goals of spine surgery, while incurring minimal collateral damage to the bones, tendons, and muscles that actively control movement and contribute to the dynamic stability of the lumbar spine.[4,7]

As stated earlier, MIS has found applications in various pathologies dealt with by spinal surgery; however, nowhere do the abovementioned tenets of MIS seem more pertinent, or the application of MIS more relevant, than in the setting of pediatric spinal surgery. The developing bones, muscles, and tendons of the pediatric spine deserve to be operated upon with no or minimal disruption to prevent subsequent spinal deformity in this age group.[15,16] There are only a few studies describing MIS techniques in the pediatric population, especially for lumbar disc herniation (LDH).[9,10,12,13] Wang *et al*. documented the use of percutaneous endoscopic interlaminar discectomy in 29 pediatric patients and expounded the advantages (minimal traumatization and scar formation) in the utilization of MIS techniques for pediatric LDH.[13] Thomas *et al*. published their series of 6 pediatric patients undergoing MIS for LDH and stated that MIS techniques can be safe and efficacious in this patient population.[12] They, however, advocated the need for a larger series to validate their findings in pediatric patients. Our case series is one such attempt and represents the safe application of MIS surgery to the pediatric patient population requiring discectomy, laminectomy, or direct pars repair. We make the case for considering this approach as a standard of care in the pediatric and adolescent population.

Rationale for pediatric minimally invasive surgery

Spine surgery inherently causes damage to the surrounding muscles, which is evidenced by atrophy and subsequent loss of function in the paraspinal muscles.[1,4] The dissection and stripping of the tendinous attachment from the posterior elements of the spine results in the disruption of paraspinal muscle function, the most prominent of these being the multifidus muscle. The detachment of this muscle renders it incapable of dynamically controlling its motion segment. Use of electrocautery in dissecting the paraspinal musculature from the posterior spinous elements causes localized thermal injury and necrosis of the musculature, further weakening the function. The powerful self-retaining retractors rampantly used in traditional spinal surgery result in decreased intramuscular perfusion and muscle denervation (caused by damage to the neuromuscular junction following prolonged retraction), and are one of the foremost causes of paraspinal muscle necrosis. The severity of muscle disruption is correlated to the degree of the intramuscular pressure and the length of the retraction time. The clinical results correlate well with cadaveric studies that show minimally invasive, table-mounted tubular retractors produce lower retraction pressures in the surrounding soft tissues compared with traditional self-retaining open retractors.[11] This damage is relatively well-tolerated in the adult spine compared to the pediatric spine,[15] because any separation of musculature and tendinous structures from their osseous origins would hamper the dynamic stability of the pediatric spine.[12,13]

Salient features of our study

Our MIS strategy in the pediatric cohort lays emphasis on the use of specialized instruments tailored to the pediatric population and refined surgical techniques to limit paraspinal osseo-tendinous complex damage. Our series is unique in that smaller tube size diameter (16 mm versus the standard 22 mm) was used to minimize tissue disruption. By utilizing smaller tube sizes, less muscle and soft tissue disruption occurs, and therefore, may decrease postoperative surgical site soreness. We focused on operative technique and appropriate patient selection to achieve optimum results. Patients without acute presentation (foot drop) underwent a trial with conservative management. Clear pathology was linked to the operative indication, carefully documented, and discussed with patients and their families.

It worth noting in our series that the average patient undergoing a discectomy in our series was considered overweight with a BMI of 29.4. The BMI cut-off for frank obesity is at 30.0. This is not terribly surprising considering the adult obesity rate in Louisiana is approximately 36.2%. The obesity rate for 18–25-year old in Louisiana is 29.0%. For 10–17-year old, the rate was 21.0%. The average BMI across the country is 26.6 for males and 26.5 for females.[3]

After lumbar discectomy, studies have noted the following biomechanical changes in the disc space: decreased disc space height, increased intradiscal load, and subsequently increased facet joint loads, which may result in further back pain. Indeed, in our series, nearly 20% of the patients experienced pain needing additional management. Although through 1–6 years of follow-up, no patients needed instrumented fusion. Admittedly, this patient cohort should be followed for a long time for evaluation and management.

Disc herniation in the pediatric and adolescent population

Disc herniation has been described as a pathological process attributed to the degenerative disease of the spine.[12] Several biochemical, environmental, genetic, and mechanical factors have been described in the etiopathogenesis of disc degeneration. Compared to adult LDH, pediatric patients presenting with LDH have unique characteristics regarding clinical findings, radiology, and causes. Unlike adult LDH, which is mostly a consequence of chronic degeneration, pediatric LDH has been linked with trauma or injuries. Many of our patients were actively engaged in high intensity sports. This included gymnastics as well as weight lifting. Thus, multiple microinjuries of the intervertebral disc may have played a vital role in the etiopathogenesis of LDH in our series.

During a discectomy procedure, the overall goal is to remove herniated nucleus pulposis. The annular tear may be widened, if needed, to remove adequate disc material. While there is controversy regarding the proper extent of removal of herniated pulposis, it has been shown that more aggressive disc removal may lead to unfavorable biomechanics. Hence, pediatric LDH requires special consideration with respect to this aspect as aggressive disc removal may result in future degenerative problems for these patients. As such, especially in the pediatric population, great care should be taken to perform a less aggressive discectomy. This technique is followed in our institution.

Spondylolytic defects in young patients

A relatively common cause of lower back pain in adolescents is congenital pars defects. By having a defect in the pars, there is increased translated motion to the facet joints, thereby causing increased pain. Spondylolytic defects of the lumbar spine has traditionally been treated using a variety of techniques ranging from conservative management to fusion. Widi *et al*. demonstrated the efficacy of direct repair of the defect in young adult patients without significant disc degeneration and lumbar instability.[14] Our series has one patient who underwent a direct pars repair for spondylotic defect. Emphasis was placed on proper patient selection. The use of MIS technique resulted in the least disruption of spinal osseo-tendinous structures.

Several operative strategies have been advocated for direct pars repair, most notably wiring along with screw technique (Morscher hook screw, Buck screw). One biomechanical study noted that screw repair was consistently the strongest and most reliable repair method.[5] Operatively, at our institution, Buck screw placement is the accepted technique. Another method which has been described and is performed at our institution in selected cases is the application of allograft such as BMP for noninstrumented pars fusion. Direct pars repairs have been somewhat common in young adolescent athletes with intractable lower back pain. Some success has been reported with direct pars repair in this population.[8] Thus, we document the successful employment of MIS technique in the repair of a pars defect in a young athlete using allograft.

Complications

One patient suffered a superficial wound infection. This patient was successfully managed with a conservative course of oral antibiotics. The patient was followed up without further sign of infection. Of note, the patient had a BMI of 30.8 but otherwise no medical co-morbidities. One patient required a revision surgery for an early recurrent disc herniation. This patient had a BMI of 36.4. Initially, the patient tolerated the procedure of a L5-S1 disc herniation well and went home immediately postoperatively with good pain control. However, on postoperative day 4, the patient experienced acute onset of dramatic radiculopathy in a similar distribution but with higher intensity than preoperatively. The patient was not performing any heavy lifting or exercises. The patient underwent a revision surgery for a recurrent disc herniation and tolerated the procedure well.

Limitations

The present study has several limitations inherent to its retrospective nature. Information was limited by chart availability and short-term follow-up period of 6 months. Specifically, this incorporates operative decision planning and rubric for the entire conservative treatment algorithms. Furthermore, as indicated, one specific patient was lost to follow-up. While not abnormal in our patient population, this provides incomplete information regarding long-term operative outcome.

CONCLUSIONS

Technical advances in MIS allow for application to a wider patient population. Our series illustrates the safe and effective application of MIS techniques to carefully selected pediatric and adolescent patients. The emphasis during surgery should be on minimal tissue and biomechanical disruption for this patient population.

Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Conflicts of interest

There are no conflicts of interest.

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Commentary

This study concludes that minimally invasive spine surgery (MIS) performed by a single fellowship-trained academic spinal neurosurgeon was both safe and effective based on a series of only 16 pediatric/adolescent patients. However, this claim is not adequately supported by these data. How could they conclude that 90% of patients had no complications at 6 postoperative months? They report that: 1 developed a recurrent disc, 1 had a superficial wound infection, 1 required continued pain management, and most critically, 1 had a foot drop. This is hardly what one should consider a good result. I submit that the appropriate conclusion is that MIS is contraindicated in the adolescent/pediatric age group. Had these patients undergone an open microscope-assisted procedure, they more likely than not, would have avoided at least 3 of the 4 complications, as there would have been enough room to maneuver to perform a more complete disc removal to avoid disc recurrence, and avoid inadvertent nerve root manipulation resulting in the residual pain syndrome and foot drop.

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