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An analysis of the differences in the acute hospitalization charges following minimally invasive versus open posterior lumbar interbody fusion

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Clinical article

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Object. Minimally invasive spine (MIS) procedures are increasingly being recognized as equivalent to open procedures with regard to clinical and radiographic outcomes. These techniques are also believed to result in less pain and disability in the immediate postoperative period. There are, however, little data to assess whether these procedures produce their intended result and even fewer objective data to demonstrate that they are cost effective when compared with open surgery.

Methods. The authors performed a retrospective analysis of hospital charges for 1- and 2-level MIS and open posterior interbody fusion for lumbar spondylotic disease, disc degeneration, and spondylolisthesis treated at a single academic medical center. Patients presenting with bilateral neurological symptoms were treated with open surgery, and those with unilateral symptoms were treated with MIS. Overall hospital charges and surgical episode–related charges, length of stay (LOS), and discharge status were obtained from the hospital finance department and adjusted for multi-/single-level surgeries.

Results. During a 14-month period, 74 patients (mean age 55 years) were treated. The series included 59 single-level operations (75% MIS and 25% open), and 15 2-level surgeries (53% MIS and 47% open). The demographic profile, including age and Charlson Comorbidity Index, were similar between the 4 groups. The mean LOS for patients undergoing single-level surgery was 3.9 and 4.8 days in the MIS and open cases, respectively ($p = 0.017$). For those undergoing 2-level surgery, the mean LOS was 5.1 for MIS versus 7.1 for open surgery ($p = 0.259$). With respect to hospital charges, single-level MIS procedures were associated with an average of $70,159 compared with $78,444 for open surgery ($p = 0.027$). For 2-level surgery, mean charges totalled $87,454 for MIS versus $108,843 for open surgery ($p = 0.071$). For single-level surgeries, 5 and 20% of patients undergoing MIS and open surgery, respectively, were discharged to inpatient rehabilitation. For 2-level surgeries, the rates were 13 and 29%, respectively.

Conclusions. While hospital setting, treatment population, patient selection, and physician expectation play major roles in determining hospital charges and LOS, this pilot study at an academic teaching hospital shows trends for quicker discharge, reduced hospital charges, and lower transfer rates to inpatient rehabilitation with MIS. However, larger multicenter studies are necessary to validate these findings and their relevance across diverse US practice environments. *(DOI: 10.3171/2009.12.SPINE09621)*

Key Words • **minimally invasive surgery** • **economic analysis** • **cost analysis** • **length of stay** • **complications** • **spine surgery** • **socioeconomic study**

Minimally invasive surgery for spinal decompression, fixation, and fusion has recently become popularized and well accepted for the treatment of lumbar degenerative disease. The development and widespread availability of instruments and implants have additionally resulted in use of these MIS techniques in community and academic neurosurgical practices.[6,10–12,20,22] Because of a reduced destruction of the soft tissues, proponents of these MIS techniques claim to achieve superior clinical results with reduced postoperative pain, narcotic use, and hospital LOS. While these claims have not been conclusively validated in controlled studies, the public's desire for improved clinical outcomes frequently leads to a preference for the MIS approach.

Because the general goals of MIS and open spinal

Abbreviations used in this paper: CCI = Charlson Comorbidity Index; LOS = length of stay; MIS = minimally invasive surgery; rhBMP-2 = recombinant human bone morphogenetic protein–2.

surgery are similar, it would be anticipated that the long-term clinical outcomes are similar, as pain and disability from muscle dissection and subperiosteal stripping resolve in the vast majority of patients.[9] However, in the perioperative period, the advantages of MIS, which include performing the surgery with less muscle trauma and blood loss, should result in cost savings during the acute hospitalization.

Cost savings due to improved early outcomes have been well documented with the introduction of other minimally invasive surgical procedures, such as laparoscopic gastrointestinal surgery,[21] minimal access total hip arthroplasty,[5] and thoracoscopic surgery.[13] However, it is also possible for MIS techniques to become so complex as to result in substantially longer operative times, which when combined with increased capital equipment costs, can make these procedures less cost effective, as has been the case with certain robotic surgeries.[14,16] In addition, less effective techniques may also result in short-term cost savings but defer the definitive surgical treatment, as was seen with procedures such as chemonucleolysis.[15]

Given the high prevalence and increasing growth in lumbar spinal fusion in the US, there has been great interest in reducing the costs associated with these treatments.[23] Thus, any potential impact spinal MIS may have on the acute care costs could prove significant from a health care economics perspective. However, to date there has been little published in this area with respect to MIS for the spine. This study reviews our experiences with hospitalization costs at an academic medical center.

Methods

Patient Population and Selection

Following institutional review board approval, a continuous series of patients undergoing lumbar interbody fusion over a 14-month period was collected and retrospectively reviewed. All patients were treated at Jackson Memorial Hospital, a 1550-bed county hospital that serves as the major surgical center for private and public spine surgery patients at the University of Miami Miller School of Medicine. A total of 74 adult patients were included in the study. All patients underwent elective admission for surgery and were living independently and ambulating with or without the assistance of a cane or walker. Preoperative symptoms included lower-extremity pain due to lumbar nerve root compression and axial back pain. Patients undergoing surgery solely for radiculopathy were excluded. Pathologies included spondylolisthesis, spinal stenosis, and degenerative disc disease. Patients with spinal deformities from a spondylolisthesis grade of greater than 2 and those with coronal malalignment of more than 20° were also excluded.

Surgeries were performed by a single attending surgeon. Clinical outcomes, complications, discharge status, LOS, and Prolo scores[1,18] were abstracted through chart review. Acute care hospitalization costs were obtained from the hospital's finance department and were based on actual hospital charges and not adjusted for contracting, insurance status, or actual payments received. Surgical implant costs did not differ between surgical procedures except by the number of levels treated due to construct-based pricing. Statistical significance was assessed using a nonpaired single-tailed T-statistic.

Patients were selected for minimally invasive versus open surgery based on their neurological symptom profile. For those with lower-extremity complaints confined largely to a single extremity, an MIS approach was undertaken given the excellent unilateral decompression it affords (Fig. 1). Patients presenting with symptoms substantially affecting both lower extremities were offered open surgery given the efficiency of bilateral decompression provided by an open surgical technique. There were no cases in this study in which patients offered open surgery underwent MIS at our institution. In addition, there were no MISs that were converted to an open procedure intraoperatively.

Surgical Techniques

The purpose of all surgical procedures was to perform a neural decompression followed by circumferential spinal fusion and fixation. With the open procedure, a midline incision followed by subperiosteal dissection was undertaken to the facet joints bilaterally. Thus, the transverse processes were not exposed. Medial facetectomies were then performed for bilateral foraminal decompressions followed by disc removal and placement of an intervertebral cage fixation device. This was followed by placement of polyaxial titanium Expedium transpedicular screws (Depuy Spine, Inc.). Bone morphogenetic protein sponges were used in MIS and open surgical procedures, standardized to 2 sponges per disc level. Thus, a small rhBMP-2 kit (InFuse, Medtronic Sofamor Danek, Memphis, Tennessee) was used for single-level surgery and a medium kit was used for 2-level surgeries. Typically 2 spacers were used for the open surgeries, but the total implant cost was controlled for by construct pricing.

For MIS, a unilateral approach was undertaken through a paramedian skin incision using the Wiltse plane. A tubular dilator retractor was then placed over the facet joint and the was joint removed, exposing the exiting and traversing nerve roots. This was followed by disc removal and placement of a carbon fiber cage and rhBMP-2 sponges. The retractor was then removed, and the pedicles of interest were cannulated using a Jamshidi needle under anteroposterior and lateral fluoroscopic guidance. This needle was then exchanged for a Kirschner wire placement, which allowed insertion of a cannulated awl, tap, and Viper pedicle screw (Depuy Spine, Inc.). The screw heads were then connected with percutaneously inserted rods bilaterally. All operations included bilateral transpedicular screw-rod fixation.

Results

Comparative Analysis of Treatment Populations

Demographic characteristics of the 4 treatment populations are summarized in Table 1. With regard to age and sex, all 4 groups demonstrated similar distribution patterns. Medical comorbidities as assessed using the CCI

Fig. 1. Postoperative radiographs showing a 2-level MIS transforaminal lumbar interbody fusion at L4–5 and L5–S1 with percutaneous transpedicular screw fixation for degenerative disc disease and unilateral radiculopathy.

and age-adjusted CCI were also similar between groups ($p = 0.34$ for single-level surgery, and $p = 0.41$ for 2-level surgery).[3]

Clinical Outcomes and Complications

Intraoperative blood loss differed significantly between MIS and open surgery. The mean difference in blood loss was 255 ml for single-level surgery ($p = 0.065$), and 306 ml for 2-level surgeries ($p = 0.001$). When analyzing for improvements in outcome following surgery, the modified Prolo scores, a well-accepted instrument for determining clinical outcomes from lumbar interbody fusion, demonstrated significant improvements in all 4 treatment groups. At last follow-up, single-level MIS resulted in a mean improvement of 3.70 aggregate points, while single-level open surgery resulted in a mean improvement of 3.47 aggregate points, a difference that was not statistically significant. Two-level MIS resulted in a mean improvement of 5.19 aggregate points, while 2-level open surgery resulted in a mean improvement of 1.57 aggregate points, a difference that was statistically significant ($p = 0.007$).

Hospitalization Costs and Patient Disposition

Differences were found with regard to hospital LOS between MIS and open surgery, as well as between single- and 2-level surgery. The mean LOS for single-level surgery was 3.9 and 4.8 days in the MIS and open cases, respectively ($p = 0.017$), as shown in Table 2. For 2-level surgery, the mean LOS was 5.1 days for MIS versus 7.1 days for open surgery ($p = 0.259$), a difference that was not statistically significant due to large variations and small sample numbers. The large variations in LOS (up to 10 days) were due to cases with pulmonary, cardiac, and infectious complications and a higher incidence of dural tears.

With respect to hospital charges, single-level MISs were associated with an average of $70,159 (range $45,908–$116,832), compared with $78,444 (range $48,788–$98,386) for open surgery ($p = 0.027$). For 2-level surgery, the mean charges totalled $87,454 (range $81,206–$101,259) for MIS versus $108,843 (range $72,240–$136,478) for open surgery ($p = 0.071$). Hospital charges correlated with LOS.

For single-level surgeries, 5 and 20% of patients undergoing MIS and open surgery, respectively, were discharged to inpatient rehabilitation. For 2-level surgeries, the rates were 13 and 29%, respectively. These costs were not accounted for in this study due to lack of outside institution financial data.

Discussion

Elective spinal surgery for degenerative disease is

TABLE 1: Demographic characteristics of the 4 treatment populations

	Group				
	1-Level		2-Level		
Chararacteristic	MIS	Open	MIS	Open	Total
no. of patients	44	15	8	7	74
age (mean ± SD)	55 ± 14	58 ± 14	55 ± 18	54 ± 11	55 ± 14
age-adjusted CCI	1.62 ± 1.74	1.8 ± 1.32	1.38 ± 1.85	1.57 ± 1.51	1.57 ± 1.55
intraop blood loss (ml)	145 ± 73	400 ± 116	187 ± 66	493 ± 169	233 ± 159
mean change in Prolo score					
pain					
preop	1.81	2.10	1.88	1.50	
postop	3.52	3.53	4.19	2.57	
change	1.71	1.43	2.31	1.07	
functional					
preop	2.74	2.93	2.94	2.71	
postop	3.73	3.87	4.38	3.07	
change	0.99	0.94	1.44	0.36	
economic					
preop	2.69	2.70	2.88	2.64	
postop	3.69	3.80	4.31	2.79	
change	1.00	1.10	1.43	0.15	
total					
preop	7.24	7.73	7.69	6.86	
postop	10.94	11.20	12.88	8.43	
change	3.70	3.47	5.19	1.57	
complications (%)					
pulmonary complications	0	0	0	14.2	
cardiac complications	0	0	12.5	28.6	
deep venous thrombosis	0	0	0	0	
dural tears	0	6.7	12.5	14.2	
neurological deficit	4.5	6.7	0	0	
wound infection	0	0	0	14.2	

typically performed to reduce pain and increase functionality. Thus, patient outcomes and the costs associated with the benefits of this treatment are critical factors for determining the value of these interventions.[8] Numerous previous studies have investigated the relative costs and benefits of spinal surgery and have found these interventions to be meaningful.[7,24] For example, in the Finnish study by Räsänen et al.,[19] the cost per quality-adjusted life-year was €1738 for lumbar surgery, making spinal surgery more cost effective than hip replacement surgery and angioplasty.

While open lumbar surgery has been well studied with regard to acute care hospital costs, there has been little investigation into MIS in comparison with traditional methods. We recently published a comparison study demonstrating the beneficial effects of MIS when compared with open techniques with regard to clinical and radiographic outcomes.[4] This study builds on that work to explore the effectiveness of MIS through cost comparisons with open surgery.

All patients in this study were treated at a single institution by a single attending surgeon. While the comparison groups were not randomized, the demographic features were quite similar. Patients harboring significant bilateral symptoms were treated with open surgery to allow for efficient and complete direct bilateral neural decompression, while those with unilateral symptoms were treated with an MIS approach. Although bilateral symptoms may have represented more advanced or severe disease in the open surgery group (potentially leading to longer recuperative periods or greater difficulty with ambulation in the postoperative period), this was not reflected in the preoperative Prolo scores, which were similar between all groups. In addition, it should be noted that all patients underwent surgery electively and were ambulatory prior to surgery, even if they experienced distance-limited gait. Nevertheless, the issue of uncontrolled case selection remains paramount in comparative studies of open versus

TABLE 2: Hospital LOS and associated costs

Characteristic	Group				Total
	1-Level		2-Level		
	MIS	Open	MIS	Open	
no. of patients	44	15	8	7	74
LOS (days)					
mean ± SD	3.9 ± 1.06	4.8 ± 1.42	5.1 ± 4.05	7.1 ± 3.39	4.8 ± 2.12
range	2–6	2–7	3–15	2–10	2–10
p value (difference MIS vs open)	0.017		0.259		
acute hospital charges ($)					
mean ± SD	70,159 ± 13,367	78,444 ± 13,482	87,454 ± 21,348	108,843 ± 28,015	78,083 ± 17,577
range	45,908–116,832	48,788–98,386	81,206–101,259	72,240–136,478	45,908–136,478
p value (difference MIS vs open)	0.027		0.071		
discharge to home (%)	95	80	87	71	89

minimally invasive surgery. However, randomized trials in this area have been sparse, largely due to patient desire for what might be perceived as a potentially less morbid procedure. Thus, patients treated at centers specializing in MIS would be difficult to consent for randomization. Other trial designs have relied on physician selection and thus bear inherent problems with selection bias, such as the use of MIS techniques in healthier, younger patients. Our trial did not have this problem, as evidenced by the similarity in CCI between groups. Regardless, the confounding issue of unilateral versus bilateral presenting symptoms remains an important deficiency of this study.

This study identified statistically significant reductions in intraoperative blood loss in single- and 2-level surgeries, and reduced LOS and acute care hospitalization charges with single-level surgeries. The rates of discharge to home were higher with the MIS group, and the postoperative complication rates were higher with open surgery. These complications accounted for a substantial portion of the variation in hospital charges, particularly in the 2-level open group. Patients who developed postoperative pulmonary or cardiac complications underwent extended hospitalizations with the need for additional testing and medical therapies. In addition, the higher rate of CSF leaks led to prolongation of bed rest, extending the hospital stay and associated costs. This is similar to the findings of Calderone et al.,[2] who identified a 4.7-fold increase in hospital charges when patients with an instrumented lumbar fusion developed a postoperative infection.

Besides the LOS, other factors also accounted for the variation in hospital charges. For example, the use of banked blood for transfusion, length of time in the operating room, the need for repeated laboratory tests to track electrolyte or blood component abnormalities, postoperative imaging, and the number of occupational and physical therapy sessions. However, this study likely underestimates the differences between open surgery and MIS because we did not account for the additional cost of discharge to a nursing facility or inpatient rehabilitation, which was more common following open surgery. This study also did not address the potential delayed costs of pseudarthrosis and adjacent-segment surgeries, which may vary depending on whether an MIS or open technique is used. Ultimately, longer-term studies will be required to address those issues.

It should, however, be noted that patients treated in this study were treated similarly after surgery regardless of the type of surgery they received. Patients were discharged home after they were able to ambulate independently and had acceptable pain control with oral medications. There were no clinical pathways to speed discharge with either group, and efforts were made to avoid an expectation bias of accelerated recovery with MIS. This is evidenced by the long (mean 3.9 days) LOS for patients undergoing MIS single-level fusions, a LOS longer than that seen at many community hospitals. In addition, the costs of implants and rhBMP were nearly identical in both groups and differed only by the number of spinal levels treated.

Drawbacks of This Study

In addition to the lack of randomization, there remain several drawbacks to this study. First, this study analyzed hospital charges and not hospital costs. This reflects not only the wholesale cost associated with any goods or services, but also an additional markup, which varies among hospitals. This accounts for the relatively high figures associated with these interventions, which occurred at a tertiary care academic medical center and county hospital. Our mean charge was $78,083, in comparison with the previous studies on transforaminal lumbar interbody fusion by Patel et al.[17] ($34,660 not including BMP), and Whitecloud et al.[24] ($33,784). The high charges are also accounted for in part by the older and more debilitated population being treated in this study, which consisted mostly of retired individuals. This was reflected in the higher CCIs, rates of medical complications, and need

for discharge to an inpatient facility. These factors would have been less prevalent in a younger, healthier population, such as those being treated for work-related injuries. Thus, it may be difficult to generalize our results to other neurosurgical practices with a different demographic population.

Second, this study did not compare long-term results between the 2 types of surgical procedures. Delayed revision surgeries or the treatment of adjacent-segment problems may differ between the groups. Furthermore, the perioperative charges do not account for any outpatient treatments, such as therapy, medications, and imaging that may have differed between groups.

Conclusions

Minimally invasive lumbar interbody fusion is a safe and effective method for decompressing and fusing the spine. While this study is limited by comparing patients with unilateral versus bilateral lower-extremity symptoms, we demonstrate a trend toward cost savings when using an MIS approach compared with traditional open surgery in the correct patient candidates. These differences are due to shorter hospital LOS, lower inpatient resource utilization, and reduced complication rates.

Disclosure

Dr. Wang is a consultant for Depuy Spine, Aesculap Spine, and Biomet Spine.

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