



Using minimally invasive techniques adds to the value equation for select patients

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Abstract: Conditions of the spine are one of the most prevalent causes of global disability, and result in a considerable portion of total health expenditures. Surgical treatment of the spine has been demonstrated in multiple studies to be a cost-effective treatment option for many patients, especially with continuing improvements in surgical technique and instrumentation. Minimally invasive spine surgery (MISS), in particular, has evolved as a valuable option in treating certain patients. Numerous studies have analyzed minimally invasive techniques in regards to cost-effectiveness and other purported advantages. These advantages include conduciveness to outpatient settings, better perioperative and immediate post-operative benefits, and faster time to recovery. This article will describe the current literature on the advantages of MISS, specifically in regards to value and cost savings.

Keywords: Minimally invasive spine surgery (MISS); value; cost-effectiveness; patient selection; ambulatory spine surgery; recovery

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Introduction

Conditions of the spine are currently the leading cause of global disability (1). The Global Burden of Disease 2010 Study demonstrated that more than any other condition, low back pain ranked highest in terms of years lived with disability, resulting in about 83 million disability adjusted life years (DALYs) lost. This DALY value is significantly higher compared to that in 1990, when low back pain resulted in only about 58.2 million DALYs lost. Furthermore, spine care incurs significant costs for all stakeholders—healthcare providers, payers, employers, and the patient. In the United States, low back pain and neck pain accounted for the third-highest percentage of healthcare spending after diabetes and ischemic heart disease, with an estimated direct expenditure of \$87.6 billion in 2013 (2). When indirect costs such as productivity loss are also added into consideration, the total cost of spine care is nearly

\$100 billion annually (2). Previous studies have shown that the cost of managing spine conditions has dramatically increased in the last few years (3). However, whether this continuously increasing cost has resulted in improved outcomes has yet to be fully established. As the population continues to age and the prevalence of spine conditions is expected to correspondingly increase, there is a significant need to more thoroughly evaluate value in different modes of spine treatment.

For most spine conditions, treatment initially focuses around non-surgical methods, including physical therapy, medications, and steroid injections. When patients do not respond adequately to these non-surgical treatments, surgical options may be considered. Studies have shown that surgical treatment of the spine is a cost-effective option in the treatment of cervical and lumbar pathologies if the patient presents with the appropriate indications (4-7). Surgical techniques in spine have continued to evolve with a particular

emphasis on minimally invasive techniques. Recent studies have shown that utilizing minimally invasive spine surgery (MISS) may potentially be more cost-effective than utilizing open techniques (8-11). Though knowledge is still expanding in regards to the various advantages of MISS, MISS has been purported to result in shorter operative times, shorter hospital length of stay, and faster return to activities of daily living compared to open spine surgical techniques (12-16). Furthermore, they lead to less muscle/tissue damage, less estimated blood loss (EBL), perioperative pain, and narcotics usage post-operatively (12-16).

The purpose of this review paper is to discuss the current literature on the various advantages of MISS compared to conventional methods, specifically in terms of value and cost savings. The paper briefly discusses patient selection for MISS, as patient selection is crucial to satisfactory outcomes in certain minimally invasive techniques. The paper also briefly discusses Ambulatory surgical centers (ASCs) for spine surgery, which are outpatient centers that usually offer care at a lower cost. As some MISS patients experience less pain and recover faster, MISS may be more conducive to this particular type of setting more so than do open techniques. The cost-effectiveness of MISS compared to open techniques is also addressed throughout the entirety of the review.

Patient selection to optimize value in MISS

Patient selection criteria for MISS has evolved significantly in the past years. For minimally invasive lumbar interbody fusions, the indications now include adult degenerative scoliosis (ADS), degenerative disc disease (DDD), lumbar stenosis, and many more (17). For minimally invasive transforaminal lumbar interbody fusion (MI-TLIF) specifically, the patient selection criteria are very similar to open TLIF (17,18). Other than high-grade spondylolisthesis, MI-TLIF is currently being used to treat radiculopathy associated with DDD and spondylolisthesis. In certain situations, such as in recurrent disc herniations, MI-TLIF may even be favored over the traditional approach (18). For adult deformities, MISS techniques have been traditionally reserved only for the correction of coronal deformities, specifically for patients with Cobb angles less than 30 degrees or greater than 30 degrees with minimal sagittal imbalance (17). With the current advent of newer techniques, such as MIS anterior column realignment, patient indications have greatly expanded. However, even with these new advancements,

MIS techniques are still limited in use in severe sagittal imbalance (Schwab osteotomy of >5, etc.) and in more complicated cervical/thoracic deformities. Patient selection for minimally invasive cervical surgeries is also an important determinant of satisfactory outcomes, as well. Skovrlj and Qureshi conducted a review of various minimally invasive cervical spine procedures, and concluded that current literature supports the use of minimally invasive posterior cervical laminoforaminotomy in treating single-level cervical radiculopathy (19). However, with the continuous improvement in surgical instrumentation and technique, it can be expected that patient indications for minimally invasive cervical procedures will continue to expand as well.

ASCs

ASCs, or surgical centers that perform same-day or outpatient elective procedures, have evolved significantly due to a combination of governmental policies and advancements in surgical techniques, with over 20 million procedures being performed in ASCs in 2011 (20). The potential advantages of ASCs include several factors including lower cost due to lack of hospitalization-related expenditures, specialization, and similar operative outcomes with shorter operative times, compared to inpatient hospital setting procedures (21,22). Spine surgery, with advancements in minimally invasive techniques and in surgical instrumentations in the past decades, has also transitioned significantly into ASCs (23-25). Some of the more commonly performed spine procedures at ASCs currently include anterior cervical discectomy and fusions (ACDFs), lumbar decompressions, MISS, and various lumbar interbody fusions.

Due to this growth of spine surgery in ASCs, numerous studies have analyzed the safety and efficacy of various MISS in ASCs. Sivaganesan *et al.* conducted a systematic literature review comparing outcomes between various spine surgeries performed in the outpatient and inpatient hospital settings, including ACDF, posterior cervical foraminotomy (PCF), cervical arthroplasty, lumbar microdiscectomy and laminectomy, and MI-TLIFs (26). In regards MI-TLIF, the authors found comparable outcomes between the two settings, including similar patient-reported outcome measures, readmission/re-operation rates, and complication rates. Smith *et al.* conducted a retrospective analysis of 1,033 patients who underwent minimally invasive lateral lumbar interbody fusions (LLIF) in outpatient settings, and found minimal perioperative complications and no emergent transfers to hospital settings (27). They also

found patient characteristics most predictive of satisfactory outcomes, specifically patients who are younger with lower body mass index, less advanced diagnosis, and higher baseline hemoglobin levels were more likely to have early postoperative discharge, with the number of lumbar levels treated and hemoglobin levels being most predictive.

Patient indications for ASCs continue to grow. Hudak *et al.* demonstrated that minimally invasive lumbar endoscopic laminotomy and foraminotomy in ambulatory settings for obese patients showed significant improvement in patient-reported outcome scores, with a negligible complication rate (28). Hirsch *et al.* in 2018 demonstrated that revision minimally invasive lumbar decompressions (MIS LDs) performed at ASCs led to similar perioperative outcomes compared to revision MIS LDs performed in a hospital setting in certain patient populations (29). The literature on the safety and efficacy of performing MISS in ASCs continues to expand, with current studies aiming to analyze these variables in a broader range of minimally invasive surgeries.

Cost savings is a significant advantage of transitioning to ASCs for any form of surgery, and spine surgery is no exception. Silvers *et al.* estimated greater than \$100 million in cost savings if all single- and two-level ACDFs were performed in an outpatient setting instead of inpatient (30). Bekelis *et al.* reported a significantly lower cost associated with outpatient lumbar discectomy compared to inpatient lumbar discectomy (24). Multiple other studies have supported these cost-saving measures in other commonly performed surgical measures (23,31).

A common theme among all of these studies is that patient selection is crucial for optimal outcomes ASC spine surgery. Certainly, patients who are older or have significant medical comorbidities would necessitate the presence of an appropriate medical care team provided by an inpatient setting. This means, however, that patient selection bias can act as a confounding variable in these cost analyses. As was mentioned previously, younger and healthier patients are more likely to undergo spine surgery at ASCs, rendering it more difficult to properly assess the true complication rates and outcome measures. Mundell *et al.* conducted a meta-analysis analyzing patient selection and perceived cost savings in outpatient spine surgery (32). In the beginning of their review, they hypothesized that the significantly lower cost associated with outpatient spine surgery is due to the inherent patient selection bias in ASCs. The authors found that the perceived initial cost savings is actually less than what is currently reported in literature, estimated to

be about \$555 in cost savings for patients aged 30–35 and \$7,290 in cost savings for patients aged 65–70. As spine care is increasingly becoming one of the biggest areas of focus for cost reduction and transition to ASCs are seen as a potential solution, future studies will need to evaluate the true cost savings associated with ASCs, and especially MISS performed in ASCs.

MISS and cost/value

Historically, cost-effectiveness and value of spine surgery has been a rather controversial topic, and analyzing cost-effectiveness of any spine procedure has not been a straightforward endeavor due to the heterogeneity of data in the literature. Analysis of cost savings in MISS has also been difficult for the same reasons. Briefly, some of the widely accepted method of analyzing cost in healthcare is the cost-utility analysis (CUA), which is calculated as cost divided by quality-adjusted life years (QALYs). QALYs view a patient's health state as a combination of length of life and quality of life lived during those years. As such, QALYs are calculated by multiplying the number of years spent in a particular health state by the utility of existing in that health state (3). Current studies in literature utilize both the QALY and direct cost savings to analyze cost-effectiveness.

The current literature on the cost-effectiveness of MISS are varied. Theoretically, MISS should be more cost-effective when compared to open techniques. MISS techniques lead to smaller incisions and less tissue/muscle damage; as such, certain minimally invasive techniques lead to shorter operative time, less blood loss, fewer surgical site infections, fewer post-operative narcotics, shorter length of hospital stays, and faster return to activities of daily living. Here, we analyze some of the current literature on these purported benefits of MISS, all of which have impact toward cost-effectiveness of MISS compared to open surgery.

Perioperative and short-term benefits of MISS versus open spine surgery

Numerous studies have reported on the above listed perioperative and short-term benefits of MISS over open spine surgery. Skovrlj *et al.* conducted a systematic literature review on the differences between MISS and open laminectomies, direct lateral fusions, and TLIFs in regards to various perioperative and outcome measures, including hospital length of stay, EBL, and perioperative pain (15).

The authors found that minimally invasive laminectomies resulted in shorter hospital length of stay and less perioperative pain, but with longer operative times. MI-TLIFs additionally had less EBL and hospital length of stay, but the data was insufficient to suggest less perioperative pain. The authors did not find a sufficient number of studies comparing minimally invasive and open direct lateral approaches.

More recently, McClelland and Goldstein conducted a systematic literature review analyzing randomized controlled trials that compared MISS and open techniques, specifically in regards to treating cervical disc herniations, lumbar disc herniations, and posterior lumbar fusions (33). For cervical disc herniations and lumbar disc herniations, the authors found no significant differences in post-operative function or pain relief. However, for posterior lumbar fusions, the authors found that MI-TLIF was associated with fewer medical complications, better post-operative patient-reported outcome measures, but higher revision and readmission rates. Al-Khouja *et al.* also conducted a literature review of eligible studies that reported cost associated with MISS (34). In their analysis of 12,425 patients, they found that MISS was associated with shorter hospital length of stay (0.93 to 5.1 days) when compared to open surgery (1.53 to 12 days).

Rates of reoperation seem to depend to an extent on the type of MISS being performed. Ng and Cheung conducted a systematic literature review of ten randomized controlled trials analyzing differences between MISS and open techniques in regards to treating lumbar spinal stenosis (35). Though the authors found that MISS reduces operative time, length of hospital stay, and creatinine phosphokinase-skeletal muscle levels post-operatively, they also found that there is insufficient data to conclude MISS leads to fewer rates of reoperation. A more recent study by Nayar *et al.* analyzed rates of reoperation in patients undergoing lumbar decompression using either minimally invasive or open techniques in a multi-institution setting (36). The authors found that the minimally invasive approach of lumbar spine surgery led to a significantly lower rate of reoperation compared to open techniques in these 2,060 patients.

Overall, perioperative complication profile for certain minimally invasive techniques has been considered better than open techniques. Wong *et al.* studied the complication profiles of 513 patients undergoing MI-TLIF, and found that the perioperative complication profile was similar or better than the complication profile of open techniques reported in literature, with durotomy and surgical site infection as

the most common perioperative complication overall (37). The authors also found higher surgical site infection rates in revision and multi-level MI-TLIF cases, suggesting that patient selection is paramount for satisfactory outcomes. In terms of patient selection, an interesting advantage of using MISS, reported by Park *et al.*, is that overweight and obese patients undergoing MIS LDs do not seem to have an increased risk of perioperative complications, like they do in open lumbar surgery (38). If more studies confirm the findings in this study, this ability to safely perform spine surgery in this patient population can potentially serve a significant advantage of MISS in the future.

Overall, as per these findings above, MISS does seem to have many perioperative and outcome benefits over open techniques, all of which can impact cost analysis. The same study by McClelland and Goldstein discussed above found that MI-TLIF was associated with a significantly reduced 2-year societal cost compared to open techniques (33). Al-Khouja *et al.* in their systematic literature review also analyzed current literature on cost-effectiveness in MISS (34). Their preliminary findings indicated that MISS leads to greater cost savings and better outcomes compared to open techniques, though they indicate that there is insufficient number of good-quality studies. They found that minimally invasive techniques overall leads to a 2.54% to 33.68% in cost savings compared to open surgery, with shorter hospital length of stay and less EBL. Recent literature has looked to expand the cost and value analyses to various other forms of MISS. Swamy *et al.* have shown greater cost-effectiveness in utilizing MISS for treating ADS, with the minimally invasive transpoas technique saving up to \$27,869 compared to the open technique and resulting in 0.06 more QALYs (39). Menger *et al.* demonstrated that MISS secondary to robotic image guidance technology resulted in \$5,713 per 1-level minimally invasive thoracolumbar procedures (40). Furthermore, MISS secondary to robotic surgery resulted in an estimated \$608,546 in cost savings during a 1-year period at a single academic center. Finally, cost and value of MISS have been analyzed abroad, as well. Vertuani *et al.* conducted a study that analyzed long-term cost savings analysis of MISS open lumbar spinal fusion in Italy and the United Kingdom (41). The authors found that MISS is associated with lower cost compared to open techniques, due to lower downstream costs (cost savings of 973 and 1,666 euros in Italy and United Kingdom, respectively) and higher health-related quality of life

(HRQOL) (0.04 improvement in HRQOL over 2 years). As MISS becomes more prevalent, future studies will need to focus on conducting standardized, high-quality Level 1 studies to better establish cost-effectiveness of MISS.

Return to activities and narcotics usage

A significant portion of the total cost related to spine care stems from indirect costs due to productivity loss, including worker absenteeism and presenteeism. Though many studies have explored the clinical outcome benefits of MISS compared to open techniques as discussed above, the topic of return to activities of daily living, such as return to work, has not been as thoroughly analyzed. Recently, however, Wang *et al.* conducted a systematic literature review that compared time to return to work and narcotic use in patients who underwent lumbar spinal fusion using minimally invasive or open techniques (16). In their analysis, of the four studies that directly compared return to work and narcotics use between minimally invasive and open TLIFs, three showed that patients who underwent MI-TLIF returned to work significantly earlier and at a significantly greater rate compared to those who underwent open TLIF. The same studies also reported that MI-TLIF patients had a shorter length of narcotic use post-operatively (mean of 2.6 weeks post-operatively) compared to open TLIF patients (mean of 6.5 weeks post-operatively).

Return to activities after spine surgery is a complex variable that depends on a multitude of factors. Asher *et al.* recently created a predictive model of a patient's ability to return to work after undergoing elective lumbar spine surgery for degenerative conditions (42). In their model, some of the most predictive factors for returning to work (in their cohort of 4,694 patients from a multicenter registry) were worker's compensation, being employed but not working at the time of presentation due to the lumbar condition, the type of employment, education level, pre-operative patient reported outcome measure scores, and certain demographic factors. This predictive model could potentially help healthcare providers give their patients and the patients' employers a better sense of when exactly the patient could expect to be back to work post-operatively. As such potential exists, future studies should look at whether this model could also apply to minimally invasive lumbar fusion, or creating a new predictive model altogether for a patient's ability to return to work after minimally invasive lumbar fusion. Furthermore, to the best of our knowledge, no study has yet looked at differences in return to other

activities of daily living between MISS and open techniques, such as return to driving and return to baseline ambulation. Future studies should focus on analyzing a broader range of activities, and on collecting high quality data on return to work in MISS patients. These future findings will serve as a vital source of information in analyzing potential cost savings of MISS from productivity losses, especially compared to open techniques.

Conclusions

As minimally invasive surgical (MIS) techniques and instrumentation continue to improve, MISS is becoming increasingly favored by a greater number of surgeons and patients. As such, the value and cost-effectiveness of MISS over open surgical techniques have been an active area of research over the past few years. MISS has been traditionally associated with lower EBL, shorter hospital length of stay, less perioperative pain, less post-operative narcotics usage, and faster return to daily activities. The nature of MISS also better allows for easier transition to outpatient ACSs. The current literature seems to lean towards the idea that with the appropriate patient selection and diagnosis, utilizing MISS can lead to better outcomes, cost-savings, and hence value addition. As was mentioned throughout the review, future studies will need to focus on gathering higher-quality data to truly ascertain long-term impact of these benefits of MISS to the overall value equation.

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Footnote

Conflicts of Interest: S Qureshi: Currently receiving consulting fees from Zimmer-Biomet, Stryker Spine, Globus Medical, Inc., K2M, OnPoint Surgical, Inc., Paradigm Spine; shareholder interest in Avaz Surgical, Vital 5; and royalties from RTI, Zimmer-Biomet, Stryker Spine; board membership at Healthgrades, Minimally Invasive Spine Study Group. SJ McAnany: Currently receiving consulting fees from Nuvasive, Titan. The other authors have no conflicts of interest to declare.

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