Minimally invasive spine surgery: Hurdles to be crossed

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ABSTRACT

MISS as a concept is noble and all surgeons need to address and minimize the surgical morbidity for better results. However, we need to be cautions and not fall prey into accepting that minimally invasive spine surgery can be done only when certain metal access systems are used. Minimally invasive spine surgery (MISS) has come a long way since the description of endoscopic discectomy in 1997 and minimally invasive TLIF (mTLIF) in 2003. Today there is credible evidence (though not level-I) that MISS has comparable results to open spine surgery with the advantage of early postoperative recovery and decreased blood loss and infection rates. However, apart from decreasing the muscle trauma and decreasing the muscle dissection during multilevel open spinal instrumentation, there has been little contribution to address the other morbidity parameters like operative time , blood loss , access to decompression and atraumatic neural tissue handling with the existing MISS technologies. Since all these parameters contribute to a greater degree than posterior muscle trauma for the overall surgical morbidity, we as surgeons need to introspect before we accept the concept of minimally invasive spine surgery being reduced to surgeries performed with a few tubular retractors. A spine surgeon needs to constantly improve his skills and techniques so that he can minimize blood loss, minimize traumatic neural tissue handling and minimizing operative time without compromising on the surgical goals. These measures actually contribute far more, to decrease the morbidity than approach related muscle damage alone. Minimally invasine spine surgery , though has come a long way, needs to provide technical solutions to minimize all the morbidity parameters involved in spine surgery, before it can replace most of the open spine surgeries, as in the case of laparoscopic surgery or arthroscopic surgery.

Key words: Controversies in minimally invasive spine surgery, learning curve for MISS, complications during learning curve, growth of MISS

Minimally invasive spine surgery (MISS) has come a long way since the description of endoscopic discectomy in 1997[1] and minimally invasive transforaminal lumbar interbody fusion in 2003.[2-4] Today, there is credible evidence (though not level-I) that MISS has comparable results to open spine surgery[5] with the advantage of early postoperative recovery and decreased blood loss and infection rates.[6]

The purpose of any minimally invasive surgery (MIS) is to minimize the damage of surgical procedure without compromising on the goals of the surgery. Every surgeon strives to achieve this during surgery and pass on the benefits of the surgical procedure to the patient without the morbidity of the surgery. Therefore, what are the parameters that constitute invasiveness of spine surgery and what are the possible measures we as surgeons can take to ensure minimal surgical morbidity for the patient?

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Most surgeons agree that the morbidity of a spine surgery increases with an increase in the following surgical variables (morbidity factors):

1. The operative time
2. Blood loss during surgery
3. Tissue handling (paraspinal muscles) and retraction
4. Handling of neural structures.

Though generally acknowledged, we need to look into any evidence that is available to know the effect of the above surgical variables on the morbidity to the patient.

In an interesting article on invasiveness of spine surgery,[7] the authors, Mirza *et al*. have been able to correlate two parameters that statistically relate with the invasiveness of any spine surgery. These are the operative time and the blood loss during the surgery. No other parameters were found to be statistically related to the invasiveness

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of spine surgery as much as these two. Based on various component procedures of spine surgery, the authors have created an invasive index for comparison of various surgical morbidities of spine surgery. The most common morbidity of surgical site infection was found to statistically correlate with the invasiveness index of any spine surgery by an independent study.[8] Hence any minimally invasive surgical concept for spine surgery needs to address the morbidity factors described above and in particular the operative time and the blood loss.

Today, most of the spine surgeries are performed by a posterior approach and only a few pathologies require anterior approach to achieve the desired surgical goals. Accordingly, most of the techniques and access systems available for MISS are for the posterior approach.

Minimally invasive spine surgery today has become synonymous with various gadgets used to access the spinal column through the posterior approach. The posterior systems involve specially designed retractors, which give a tubular approach to the interlaminar region for decompression procedures, and the percutaneous pedicle screw-rod insertion systems. Table 1 shows the major companies in the Indian market with their minimally invasive systems for percutaneous pedicle screw-rod instrumentation and tubular retractors for minimally invasive decompression procedures.

How do these systems address the factors contributing to surgical morbidity?

BLOOD LOSS

For a single level decompression and instrumented fusion like the transforaminal lumbar interbody fusion (TLIF) procedure, the access systems marginally reduce the blood loss. This is due to the fact that the majority of the blood loss during a TLIF procedure occurs during the decompression and interbody fusion and the access systems do not have any advantage over open surgery in controlling the epidural bleeding. However, in a multilevel posterior fixation, the percutaneous pedicle screw-rod systems have a definite advantage over open instrumentation in reducing the blood loss.

Table 1: Major companies and their minimally invasive access systems available in the Indian market

MISS systems and companies	Depuy	Medtronic	Globus	Synthes
Percutaneous pedicle screw system	Viper	Sextant Longitude (multilevel)	Pivot Revolve (multilevel)	SpiRIT
Tubular retractor system	Pipelene	X-tubes quadrant	MARS	MIRA

MIRA – Minimally invasive retractor access, MARS – Minimal access retractor system

OPERATIVE TIME

The access systems do not offer any advantage over the corresponding open procedures in reducing the operative time. In fact the operative time is much higher during the learning curve and it takes a long time before a surgeon is able to accomplish the MIS surgery using the access systems in the same time as open surgery. Operative time is also increased due to the frequent use of image intensifier for percutaneous pedicle screw insertions.

PARASPINAL MUSCLES AND RETRACTION

The tubular access systems have been found to decrease the muscle damage by imaging studies and by biochemical marker studies.[9-12] However, no study has been able to show any clinical benefit of these findings and hence the advantage of paraspinal muscle preservation by the access systems is still speculative. However, the advantages of muscle preservation by percutaneous pedicle screw-rod systems may be more evident in a multilevel fixation than in a single level fixation. Wiltse's paraspinal muscle splitting approach can be used as an alternative way to adapt minimally invasive approach for pedicle screw insertion in an open multilevel fixation surgery. It is an approach via intermuscular plain and preserves paraspinal muscles similar to or better than the tubular rector systems. It is a misconception to believe that only when the access systems are used the surgery becomes minimally invasive.

HANDLING OF NEURAL STRUCTURES

The minimal access systems are actually a hindrance for a surgeon at the time of neural decompression. This is because of the narrow space available for maneuvering the instruments used for decompression and the limited narrow vision through the tubes. This is the most common reason for the reluctance of many spine surgeons from switching over to MIS through tubular retractors. The decreased access to the neural structures also contributes to the increased incidence of incidental durotomies and neural damage, especially during the learning curve for these procedures.

Are minimally invasive spinal procedures replacing the corresponding open procedures?

Minimally invasive spine surgery has not gained

wider acceptability in the field of spine surgery when compared to Laparoscopy or Arthroscopy. For example, laparoscopic cholecystectomy almost completely replaced (98% cholecystectomies done laparoscopically) open cholecystectomy within 5 years of its first description in 1987 by Phillipe Mouret.[13] Laparoscopic procedures have shown results equal or better to that of open procedures with advantages of reduced blood loss, lesser use of analgesics, shorter stay in the hospital and earlier return to work. The complication rates of laparoscopic procedures are similar to open procedures. Similarly today, there is virtually no place for open meniscectomy with superior results of arthroscopic meniscectomy. The advantages of these procedures overweigh minor disadvantages associated with them and hence these procedures rapidly replaced the open techniques.

In comparison, the growth of MISS has not been so encouraging. According to 2013 millennium group study,[14] MISS surgeries constituted about 16% of spinal fusion surgeries in the US in 2011, which increased to 18% in 2013 and predicted to reach 22% by 2017 [Figure 1]. The annular growth of MISS, which was 12.6% in 2012 is predicted to decrease to 9% by 2017 [Figure 2]. The statistics in India also shows a similar trend. The annual growth which was 135% in 2008 has plateaued to 36% in 2013, with MIS surgeries constituting 13% of the total spinal procedures [Table 2]. This indicates the need to analyze the reasons for the popularity of MIS surgeries not keeping up the pace of laparoscopic or arthroscopic procedures despite many proposed benefits over open techniques.

On analyzing technically, many hurdles can be found which come in the way of MIS technique replacing open spine surgeries. Expensive equipments, limited field of vision, steep learning curve, longer duration of surgery, higher radiation exposure, higher complication rate particularly during the learning curve are some of them. Moreover many of the proposed advantages of MIS surgeries like reduced blood loss, minimal paraspinal muscle damage, reduced cost due to shorted stay and lesser medications are derived from cohort studies[15] and no conclusive evidence can be found in the literature for support.[16]

Further, the disadvantage of MIS technique with tubular access is the limited field of vision in the interlaminar space. This may result in inadequate treatment of pathology and higher rate of complications, thereby increasing the recurrence and reoperation rates.[17] In arthroscopic or laproscopic procedures, the instruments are introduced into a fluid filled or gas filled distended cavities allowing easy maneuverability, whereas in MIS the maneuverability of the tubular retractors is limited because of closed muscular compartment, thereby reducing the field of vision.

Another well-accepted drawback of MIS technique is the risk of radiation exposure. Radiation exposure in MIS surgeries is significantly higher than open access technique.[18,19] It is estimated that a surgeon can perform a maximum of 291 MIS discectomies annually without protective gear before exposing himself to maximum allowable dosage.[18] The exposure in instrumented fusion surgeries is even higher. Even though protective gear can reduce the radiation exposure to the trunk and thyroid, reducing the exposure to other parts of the body like hands and eyes requires specialized gears, which are expensive and not available in all the centers. Yet another drawback of MIS technique is its steep learning curve.[17,20] Studies have shown that spine surgeon training in MIS requires about 44 cases to reach a stage of surgical proficiency.[17] During the initial stages of the

Measure	Technique	2011	2012	2013	2014	2015	2016	2017	CAGR (2012–2017)
Procedures	Open	491,400	509,200	527,500	545,600	563,000	578,400	593,400	3.1%
	Minimally Invasive	93,100	104,800	117,500	131,100	145,300	159,700	174,800	10.8%
	Total	584,400	614,000	645,000	676,700	708,200	738,200	768,200	4.6%
Procedures (% Growth)	Open	—	3.6%	3.6%	3.4%	3.2%	2.7%	2.6%	3.1%
	Minimally Invasive	—	12.6%	12.1%	11.5%	10.8%	9.9%	9.4%	10.8%
	Total	—	5.1%	5.0%	4.9%	4.7%	4.2%	4.1%	4.6%
Procedures (% of Total)	Open	84.1%	82.9%	81.8%	80.6%	79.5%	78.4%	77.2%	—
	Minimally Invasive	15.9%	17.1%	18.2%	19.4%	20.5%	21.6%	22.8%	—
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—

Notes: Numbers reflect rounding.

Source: Millennium Research Group

Figure 1: Data from Millennium Research Group study of US markets showing the growth and percentage of annually performed minimally invasive spine surgery fusion procedures and open spinal fusion procedures

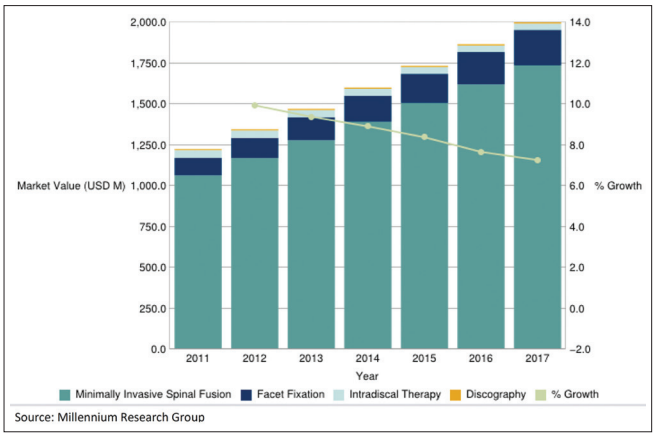

Figure 2: Millennium study depicting the product wise market for minimally invasive spine surgery in the USA (2011-2017)

Table 2: Data from Medtronic India-showing the growth of minimally invasive spine surgery in India

Year	No. of procedures		No. of surgeons doing MISS	Percutaneous. Fixation percentage versus open fixation %	MISS growth rate %
	Instrumented	Noninstrumented			
2007	45	70	12	1.66	
2008	120	150	23	3.29	135
2009	260	315	36	5.39	113
2010	470	570	56	7.68	81
2011	685	830	74	9.10	46
2012	1020	1210	95	11.26	47
2013 EST	1390	1650	125	13.13	36

MISS – Minimally invasive spine surgery

learning curve, the operative time and blood loss are significantly higher. The complications such as durotomy, implant malposition, nerve injury, nonunion are as high as 11%.[20] A systematic review on the learning curve by Sclafani and Kim[17] states that the complications are often underestimated as surgeons tend to select the patients carefully during the initial learning curve.

Majority of Studies on MISS have shown specific advantages of MIS surgeries over open access like reduced blood loss, postoperative pain, lesser analgesic requirement, shorter stay in the hospital and early return to work. However, a systematic review, Fourney *et al.* has stated that the majority of these studies are cohort and their results should be viewed with caution.[16] The reduced paraspinal muscle atrophy by MISS is said to be theoretical and studies demonstrating these by postoperative MRI and enzymatic studies are limited.[11] Moreover these studies have not shown any superior clinical results of MIS over open techniques.[12] Most of these studies have shown significantly longer operation time, higher technique related complications like incidental durotomies, malposition of screws resulting in higher reoperation rates in MIS techniques. Long-term prospective randomized controlled studies comparing open and MIS techniques are still lacking in the literature.[16] The authors of the systematic review go on to state that it is recommended that the patients opting for minimally invasive procedures should be informed that the benefits of these procedures are still unproven.[16] MISS should not be performed merely because they represent newer technology.

Ultimately, it is the acceptance of any procedure, by the surgeons and the patient, which makes it grow or become obsolete over a period of time. Any new procedure needs to address the following issues before it becomes an acceptable procedure and has sustained growth with time.

Superior results

The very purpose of performing any surgery is to give benefit to the patient despite cutting him/her open. For any new procedure to be successful, it needs to provide at least similar if not better results than the presently available procedures for the given disease. A procedure which gives consistently superior results (Surgical outcomes) than any procedure practiced presently will eventually replace the other procedures. MISS is still on the road to prove that its results are not inferior to the corresponding open procedure. In the only randomized controlled study on MISS versus open discectomy, the authors Arts *et al.*[21] found that the results of Microendoscopic discectomy was inferior to the open procedure.

Surgical access

For any procedure to have sustained growth it needs to be surgeon friendly and give good access to the pathological area. For example, Laparoscopic surgery and arthroscopic surgery; though are demanding initially with a learning curve, become surgeon friendly with the unparalleled access to the entire abdominal cavity or the knee joint, respectively. However in MISS, even after overcoming the learning curve, the surgeon has to contend with a restricted access to the pathological area through a tubular space. This can affect the surgical results and also contribute to more complications in MISS surgeries. For any minimally invasive procedure to be successful it should provide maximal access to the pathological area with minimal invasiveness.

Safety

Needless to say that for any procedure to sustain itself, safety is of prime importance. Take the example of laparoscopic anterior spinal surgery. Though, it was borne out of the success of laparoscopic surgery, it gave limited

access to the spinal column and the neural structures. It resulted in far more complications than an anterior open spinal decompressive surgery and gradually went into disrepute over a period of time. MISS has comparable complication rates to the corresponding open procedure after a surgeon overcomes the learning curve.

Cost

Though a lot of literature is available on the cost-effectiveness of MISS[22] despite it being costlier than the corresponding open procedure, we believe that cost-effectiveness should not be a matter of concern once the above three criteria are fulfilled by any new procedure. If a procedure is able to give consistently superior results with minimal complications (safety) and is also surgeon friendly, it is bound to flourish and replace other procedures whatever the cost of the procedure may be.

In Summary, the authors would like to state that MISS as a concept is noble and all surgeons need to address and minimize the surgical morbidity for better results. However, we need to be cautious and not fall prey into accepting that MISS can be done only when certain metal access systems are used. It has been shown with evidence that the available minimally invasive technologies address only one morbidity variable for minimizing the surgical morbidity that is, the posterior muscle damage. Apart from decreasing the muscle trauma and decreasing the muscle dissection during multilevel open spinal instrumentation, there has been little contribution to address the other morbidity parameters like operative time, blood loss, access to decompression and atraumatic neural tissue handling with the existing MISS technologies. Since all these parameters contribute to a greater degree than posterior muscle trauma for the overall surgical morbidity, we as surgeons need to introspect before we jump on to the concept of MISS being reduced to surgeries performed with a few tubular retractors. A spine surgeon needs to constantly improve his skills and techniques so that he can minimize blood loss, minimize traumatic neural tissue handling and minimizing operative time without compromising on the surgical goals. These measures actually contribute far more, to decrease the morbidity than approach related muscle damage alone. This is the reason why most of the studies on MISS have been unable to conclusive prove that it has superior results than its corresponding open spine surgery.[1] However, in combination with the access systems, when spine surgery can be performed by addressing the other morbidity parameters, we can further minimize the approach related morbidity in patients with obesity and multiple co-morbidities. MISS, though has come a long way, needs to provide technical solutions to minimize all the morbidity parameters involved in spine surgery, with good access to the neural structures before it can replace most of the open spine surgeries, as in the case of laparoscopic surgery or arthroscopic surgery.

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