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Clinical Study

Minimally invasive surgery compared to open spinal fusion for the treatment of degenerative lumbar spine pathologies

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ABSTRACT

This clinical study prospectively compares the results of open surgery to minimally invasive fusion for degenerative lumbar spine pathologies. Eighty-two patients were studied (41 minimally invasive surgery [MIS] spinal fusion, 41 open surgical equivalent) under a single surgeon (R. J. Mobbs). The two groups were compared using the Oswestry Disability Index, the Short Form-12 version 1, the Visual Analogue Scale score, the Patient Satisfaction Index, length of hospital stay, time to mobilise, postoperative medication and complications. The MIS cohort was found to have significantly less postoperative pain, and to have met the expectations of a significantly greater proportion of patients than conventional open surgery. The patients who underwent the MIS approach also had significantly shorter length of stay, time to mobilisation, lower opioid use and total complication rates. In our study MIS provided similar efficacy to the conventional open technique, and proved to be superior with regard to patient satisfaction, length of hospital stay, time to mobilise and complication rates.

1. Introduction

The safety of traditional open techniques for pedicle screw placement for spinal fixation is well documented.[1,2] However, conventional open spine surgery has several limitations reported including extensive blood loss, postoperative muscle pain and infection risk. Paraspinal muscle dissection involved in open spine surgery can cause muscular denervation, increased intramuscular pressure, ischaemia, necrosis and revascularisation injury resulting in muscle atrophy and scarring which is associated with prolonged postoperative pain and disability.[3–12] This approach-related morbidity is then often associated with lengthy hospital stays and significant costs.[13] Spinal fusion utilising muscle dilating approaches to minimise surgical incision length, surgical cavity size and the amount of iatrogenic soft-tissue injury associated with surgical spinal exposure, without compromising outcomes, is thus a desirable advance.[3–12]

The current trend favours minimally invasive surgery (MIS) of the spine due to lower complication rates and approach-related morbidity with minimal soft tissue trauma, reduced intraoperative blood loss and risk of transfusion, improved cosmesis, decreased postoperative pain and narcotic usage, shorter hospital stays, earlier mobilisation with faster return to work and thus reduced overall health care costs.[1,4,6–9,13–18] However, to our knowledge there is no quality published articles showing that MIS is superior to open spinal surgery. The aim of this study was to directly compare the effectiveness of MIS to conventional open spinal fusion, by assessing clinical outcomes and patient satisfaction.

2. Methods and materials

2.1. Patients

A total of 82 patients was prospectively followed during 2006 to 2010: 41 patients who had undergone an MIS spinal fusion procedure as well as 41 patients who had received the open surgical equivalent under a single surgeon (R.J.M). Patients treated within the public hospital system were allocated to the open group and within the private system to the MIS group. All patients were operated on by the senior surgeon (R.J.M.) as part of the inclusion criteria. Of these, 37 patients who underwent MIS and 30 patients who underwent open surgery were available for follow-up. Data collected on all patients included: the Oswestry Disability Index (ODI), Short Form 12 (SF-12) version 1, the Visual Analogue Scale (VAS) score and the Patient Satisfaction Index (PSI). Outcome data were collected at the final patient follow-up. Patients were included if they: were aged 18–75 years; and had a degenerative pathology only. All patients complained of either back pain, radiculopathy, claudication or a combination of these three symptoms.

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All patients had pain resistant to prolonged conservative therapy (at least six months).

Patient demographic data, preoperative ODI and VAS responses, and operative characteristics for these surgical approaches are summarised in Table 1. The indications for surgery were isthmic and degenerative spondylolisthesis, degenerative scoliosis and degenerative disc disease with canal stenosis. These were confirmed by dynamic radiographs, CT scans and MRI. The average follow-up time following MIS procedures was approximately 11.5 months (range: 5.40–20.10 months) in comparison to 18.7 months (range: 8.07–40.00 months) for open procedures.

2.2. Surgical techniques

2.2.1. Minimally invasive technique

All percutaneous pedicle screws were inserted with the use of intraoperative radiographs (image intensifier [BV Endura], Philips Electronics, Amsterdam, The Netherlands). A radiolucent operative table (Jackson Spine Table, Orthopedic Systems, Union City, CA, USA) was used. A posterior lumbar interbody fusion (PLIF) graft was inserted via a small (3–5 cm) midline incision over the disc space to be fused (Fig. 1). A laminotomy was performed under microscopic visualisation, including a bilateral medial facetectomy to allow adequate decompression. The ligamentum flavum was then resected with rhizolysis of bilateral nerve roots. The intervertebral disc was then removed and the endplates prepared. Rotatable interbody cages filled with autologous bone, with or without synthetic bone, were placed into the evacuated disc space and were rotated for distraction. Any remaining bone graft was used to fill the remainder of the disc space (Fig. 1a). After achieving haemostasis and using copious antibiotic irrigation, the wound is closed in a routine fashion with 0 vicryl to the thoracolumbar fascia, 2-0 vicryl to the subcutaneous fat and 3-0 monocryl subcuticular sutures.

Percutaneous pedicle screw–rod fixation was undertaken using the Denali/Serengeti® system (K2M, Leesburg, VA, USA) or the minimal access non-traumatic insertion system (MANTIS®) (Stryker, Kalamazoo, MI, USA). For a detailed review of the technique for percutaneous pedicle screw insertion, see[19] (Figs. 2 and 3). Confirmation of pedicle screw placement is achieved with the image intensifier. The rods are then inserted via the pedicle screw incision sites and are joined to the pedicle screw heads. Tightening of the screw head caps allows for reduction of any spondylolisthesis (Fig. 1c). The MIS retractor sleeves are then removed, and all wounds are closed via the method described (Fig. 1d).

2.2.2. The conventional open technique

The conventional open technique involves a midline incision of approximately 12 cm to 15 cm for a single level fusion, followed by stripping and dissection of paraspinal muscles from the bilateral laminae and facets. After exposure of the underlying bone, laminectomy and bilateral facetectomy are performed. Discectomy and distraction of the disc space using rotatable interbody cages were performed with the same techniques and instruments as the minimally invasive technique. Multiple systems were then utilised for pedicle screw–rod fixation via the conventional technique under direct visualisation within the same incision.

2.3. Assessment of results

Patient questionnaires were used to assess preoperative and postoperative ODI, SF-1, VAS and PSI outcomes. The ODI was scored according to the method of Mehra et al.[20] The SF-12 was scored according to the method outlined by Ware et al.[21] The VAS score was used to compare preoperative and postoperative pain on a scale of 0 (no pain) to 10 (worst pain) between the two surgical groups. PSI was utilised to gauge postoperative patient satisfaction with their corresponding procedure, where a score of 1 to 4 was provided (1 – surgery met my expectation, 2 – I did not improve as much as I had hoped but I would undergo the same operation for the same results, 3 – surgery helped but I would not undergo the same operation for the same outcome, 4 – I am the same or worse as compared to before surgery). Patients who had inadequately completed, or who had failed to complete a particular questionnaire were excluded from statistical analysis for that particular questionnaire.

Clinical data such as age, gender, preoperative symptoms, preoperative diagnosis, surgical level and operation type, length of hospital stay, time to mobilise, postoperative analgesia use, follow-up time and complications were analysed by viewing medical records. Length of stay was measured from the day of the operation (day 0) to the day of discharge. Time to mobilise was measured as the number of hours following admission to recovery until physiotherapy or nursing staff documented mobilisation of at least sit-to-stand. Along with medical records, patients were also requested to report any complications postoperatively as part of their questionnaires.

Fusion was assessed by fine-cut coronal bone-window CT scans at the final follow-up visit. The assessment of fusion was made by two independent radiologists and not by the senior surgeon or his research team.

Table 1
Demographic data for patients who underwent minimally invasive surgery (MIS) compared to open spinal fusion (open)

	MIS	Open	*p*-value
No. patients (*n*)	37	30	
Age (years ± standard deviation)	68.56 ± 12.99	67.48 ± 13.19	0.7379
Gender (M/F) (% male)	19/18 (51.35)	16/14 (53.33)	0.8717
Follow-up time (months)	11.46 ± 4.216	18.69 ± 8.129	<0.0001
Preoperative diagnosis (no. [% of patients])			
Isthmic spondylolisthesis	4 (10.81)	9 (30.0)	0.0650
Degenerative spondylolisthesis	18 (48.65)	9 (30.0)	0.1406
Degenerative scoliosis	1 (2.70)	4 (13.33)	0.1649
Disc disease and canal stenosis	14 (32.43)	8 (26.67)	0.7890
Single level fusion (no. [% of patients])	29 (78.4)	25 (83.3)	0.6101
T11/12	0 (0)	1 (3.3)	
L2/3	1 (2.7)	0 (0)	
L3/4	2 (5.4)	0 (0)	
L4/5	20 (54.1)	15 (50.0)	
L5/S1	6 (16.2)	9 (30.0)	
Multi-level fusion	8 (21.6)	5 (16.7)	
Preoperative ODI	54.56% ± 19.47% (*n* = 34)	52.38% ± 17.25% (*n* = 26)	0.7825
Preoperative VAS	7.917 ± 1.505 (*n* = 36)	8.259 ± 1.573 (*n* = 29)	0.2113

F = female, L = lumbar, M = male, ODI = Oswestry Disability Index, S = sacral, T = thoracic, VAS = Visual Analogue Scale score.

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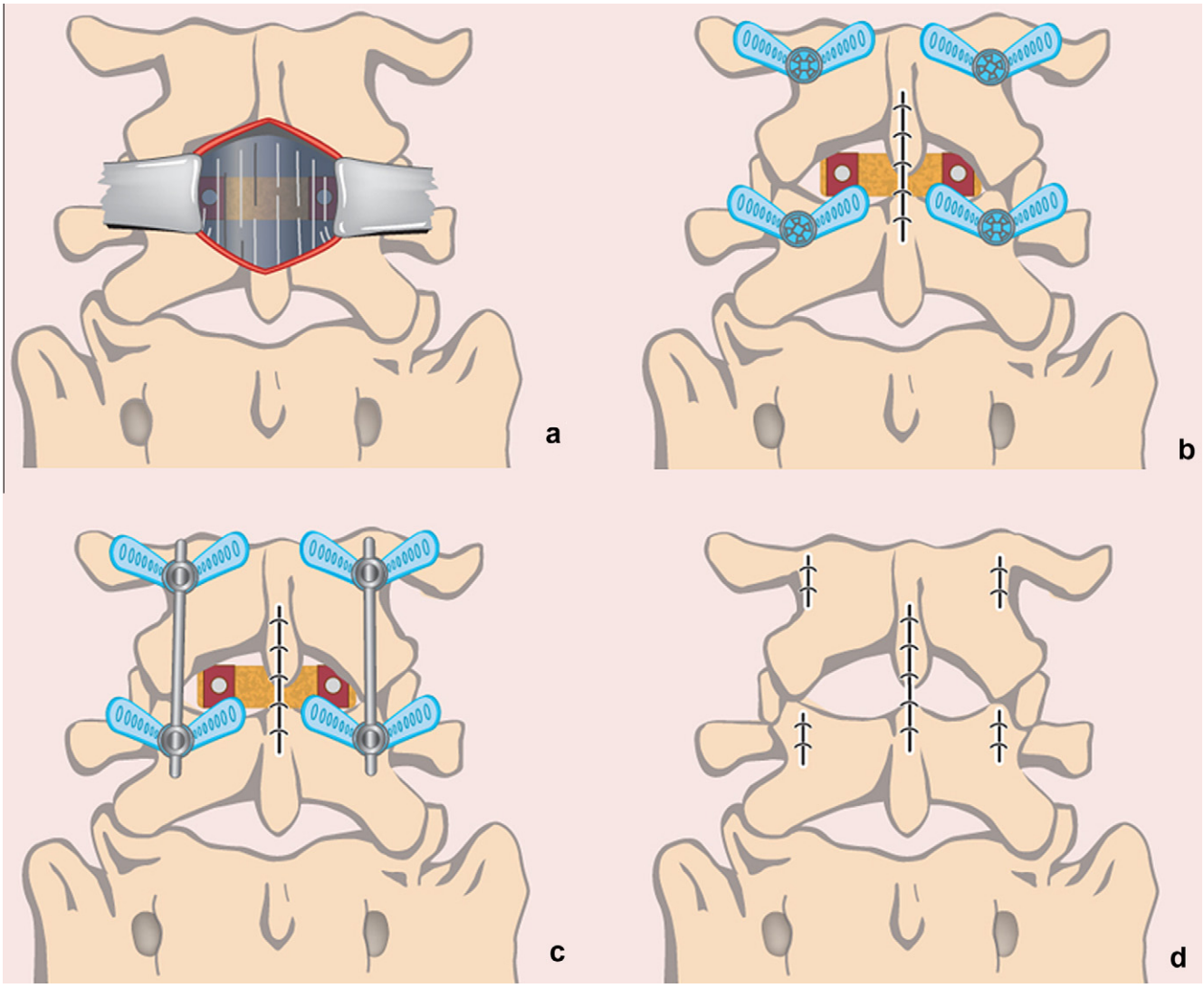

Fig. 1. Schematic diagram of a minimally invasive spinal fusion technique for a posterior lumbar interbody fusion: the "80/20 technique": (a) midline incision with the use of trimline retractor system to directly visualise the disc space for discectomy and insertion of rotatable interbody cages; (b) closure of midline incision and insertion of percutaneous pedicle screws; (c) insertion of rods joining ipsilateral pedicle screw heads; and (d) closure of wounds over pedicle screws. (This figure is available in colour at www.sciencedirect.com.)

Postoperative analgesia in hospital until discharge was also analysed as an indirect measure of postoperative surgical pain, as pharmacological agents are the cornerstone of acute postoperative pain management.[22,23] Drugs used for postoperative pain include weak analgesia (paracetamol, non-steroidal anti-inflammatory drugs [NSAID]), opioids and adjuvants (antiepileptics, antidepressants).[24] Pain medications that the patient was consuming prior to surgery for other conditions (for instance, arthritis) that were continued postoperatively during their hospital stay were included if they were opioids, NSAID or paracetamol as they would also contribute to treating postoperative pain. Potency refers to the power of a medicinal agent to generate its desired outcome; thus, for analgesic medication, it is the dose required to produce a given analgesic effect.[22,25,26] In a similar fashion, equianalgesia refers to different doses of two agents that provide approximate pain relief.[22] To our knowledge, there is no quality literature directly comparing opioids, NSAID and paracetamol with regard to equianalgesia.[24] To analyse postoperative analgesia, the drugs administered were divided into two groups: opioid and non-opioid analgesia.

Equianalgesic tables list opioid doses that produce approximately the same amount of analgesia based on bioavailability and potency.[22,26–28] Table 2 illustrates the range of equianalgesic dose equivalents found in our literature search.[22,25–32] To determine the total postoperative opioid utilisation by an individual patient, we converted each opioid the patient had consumed postoperatively to intravenous morphine equivalents using the equianalgesic table provided. The less traumatic surgical approach involved with MIS techniques results in less postoperative pain than conventional open techniques and is thus believed to potentially decrease postoperative narcotic use.[11,13] Non-opioid analgesia in this study refers to NSAID and paracetamol.[33]

2.4. Statistical analysis

Unpaired *t*-tests were utilised to compare normally distributed continuous data. ODI (preoperative, change), VAS (preoperative and postoperative), length of stay, time to mobilise, opioid and non-opioid usage were analysed using the Mann–Whitney *U*-test. The dichotomous variables (gender, surgical level) between the two procedures were analysed using chi-squared analysis, whereas preoperative diagnosis, PSI and complications were analysed using

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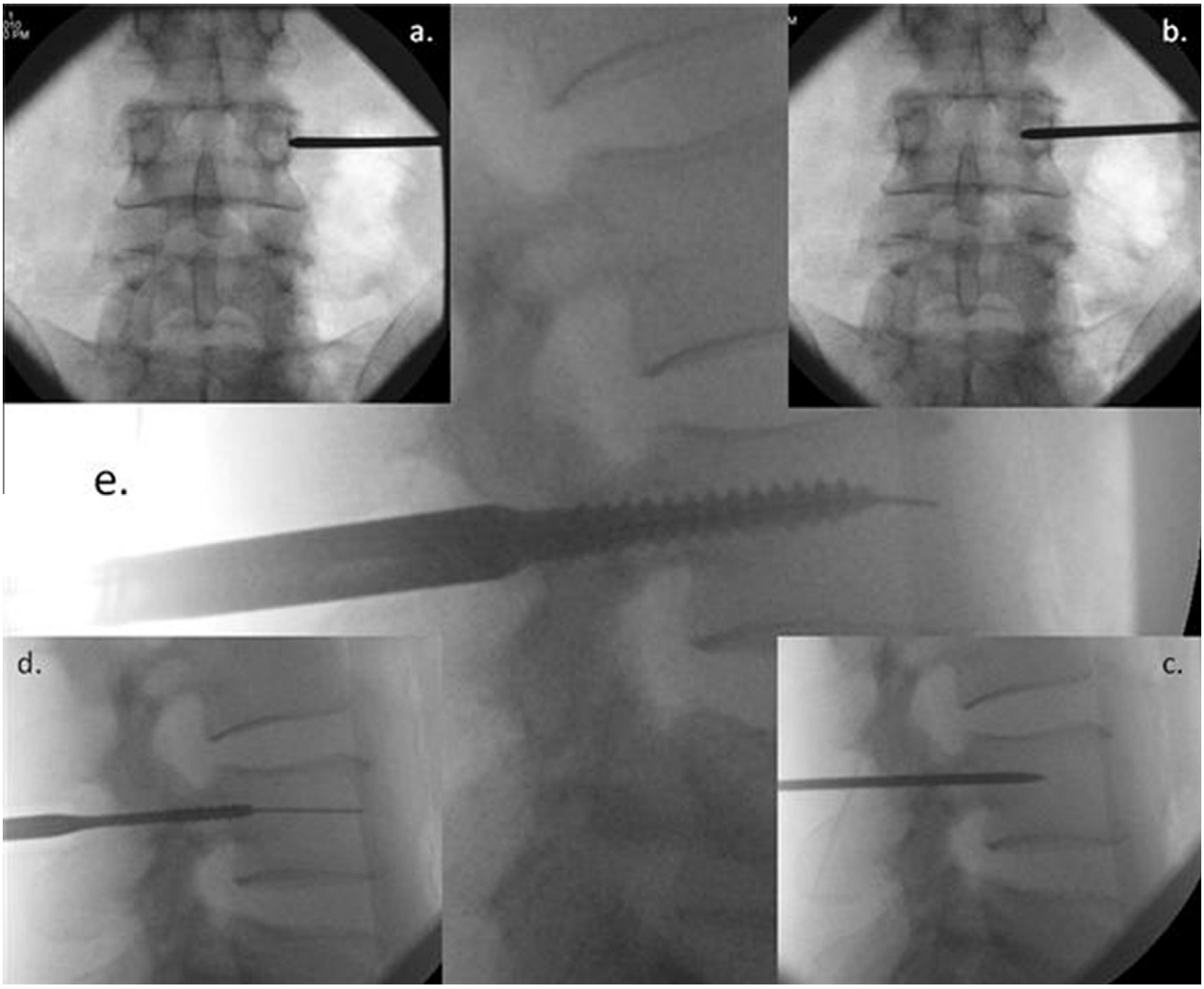

Fig. 2. Image intensifier radiographs of the percutaneous screw insertion technique showing: (a) anterior/posterior (AP) view of the Jamshidi needle docked onto the lateral aspect of the pedicle – the "3 o'clock position"; (b) AP view of advancement of the needle 20 mm to 25 mm into the vertebral body; (c) lateral view, checking the position of the Jamshidi needle; (d) lateral view, the K-wire and tapping of the pedicle; and (e) lateral view, insertion of the pedicle screw.

the Fisher exact test. A p-value of <0.05 was considered to be statistically significant.

3. Results

There was no statistical difference with respect to age, gender, preoperative diagnosis, single compared to multiple surgical levels, preoperative ODI and preoperative VAS scores between the two surgical groups. ODI and VAS was significantly lower postoperatively than ODI and VAS preoperatively among both the MIS and open procedures ($p < 0.0001$). There was no significant difference between the MIS and open procedures for postoperative ODI, SF-12 physical and mental component scores. However, the postoperative VAS pain scores were significantly lower for the MIS cohort than the open cohort ($p = 0.0144$; Table 3). A similar proportion of MIS (83.3%) and open (78.6%) patients were satisfied undertaking surgery for the benefit they received with their procedure (options 1 and 2). However, surgery met the expectations (option 1) of a significantly greater proportion of patients who had undergone MIS than the open procedure ($p = 0.0236$). The results for the PSI are illustrated in Fig. 4 and Table 4.

The MIS technique resulted in a significantly shorter hospital stay ($p = 0.0016$) and time to mobilise ($p = 0.0021$) after surgery than the open technique. The MIS group had a significantly lower postoperative usage of IV morphine (opioid) (85.90 mg) compared to the open group (168.9 mg) ($p = 0.0130$). However, the usage of non-opioids was not significantly different between the MIS and open groups (Table 5).

The complications within both groups are depicted in Table 6. There was a significantly lower complication rate utilising the MIS compared to the conventional open technique ($p = 0.0040$). There were two cases of infection with the open technique in comparison to one case utilising the MIS technique (urinary tract infection – no wound infections). One patient in the MIS group developed a painful haematoma postoperatively and presented with sacral and bilateral leg numbness. Their motor function remained intact. One patient in the open group also experienced postoperative radiculopathy. The patient was observed without treatment and the radiculopathy improved with time; however, the patient experienced long-term sensory impairment. One patient in the open cohort suffered a dural tear, with the patient complaining of headaches and vomiting following the procedure, which prolonged the length of stay. The patient was managed

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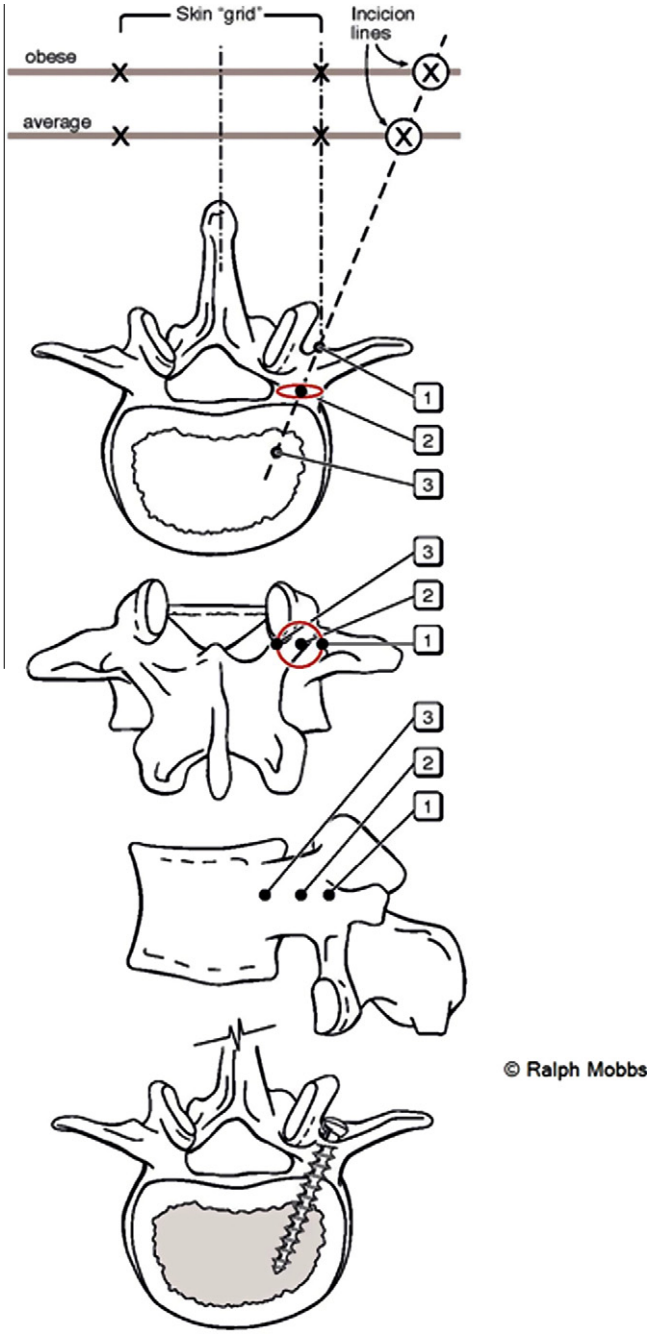

Fig. 3. Diagrams illustrating the anatomical principles of percutaneous pedicle screw insertion: views from top to bottom: (a) superior; (b) posterior, (c) lateral, (d) superior. First the initial skin incision is made with the patient's body habitus considered. Second, the Jamshidi needle is first be "docked" onto the lateral aspect of the pedicle – "position 1" – on the anterior/posterior image intensifier (II) radiograph projection. Third, the Jamshidi needle is advanced 20 mm to 25 mm so that the needle is beyond the medial border of the pedicle and into the vertebral body – to "position 3". Finally, the position is confirmed by lateral II radiograph projection before insertion of the K-wire.

Table 2
Equianalgesic opioid dose

Drug	Equianalgesic dose	
	Oral	Parenteral
Morphine	20–30 mg	10 mg
Oxycodone	15–30 mg	~15 mg
Fentanyl	–	50–200 ug
Pethidine	–	75 mg
Tramadol	100–200 mg	100–110 mg
Codeine	200–250 mg	120–150 mg
Dextropropoxyphene	130–200 mg	–
Methadone	5–20 mg	2.5–10 mg
Hydromorphone	3.75–7.5 mg (7.5 mg)	1.5 mg
Oxymorphone	10–15 mg (15 mg)	~1 mg

After: 22,25,28,30.

Table 3
Questionnaire outcomes (means ± standard deviation) for patients who underwent minimally invasive surgery (MIS) compared to open spinal fusion (open)

	MIS	Open	*P*
ODI			
Preoperative	54.56% ± 19.47% (*n* = 34)	52.38% ± 17.25% (*n* = 26)	0.7825
Postoperative	22.97% ± 16.50% (*n* = 34)	28.09% ± 16.71% (*n* = 27)	0.2357
Change	31.59% ± 19.56% (*n* = 34)	24.36% ± 17.87% (*n* = 26)	0.1153
SF-12			
PCS	41.20 ± 11.45 (*n* = 33)	36.86 ± 10.64 (*n* = 23)	0.1568
MCS	50.06 ± 8.841 (*n* = 33)	50.86 ± 10.95 (*n* = 23)	0.7634
VAS			
Preoperative	7.917 ± 1.505 (*n* = 36)	8.259 ± 1.573 (*n* = 29)	0.2113
Postoperative	2.417 ± 2.156 (*n* = 36)	3.328 ± 1.502 (*n* = 29)	0.0144
Change	5.500 ± 2.429 (*n* = 36)	4.931 ± 2.065 (*n* = 29)	0.3199

ODI = Oswestry Disability Index, SF-12 = Short Form 12 version 1, VAS = the Visual Analogue Scale score.

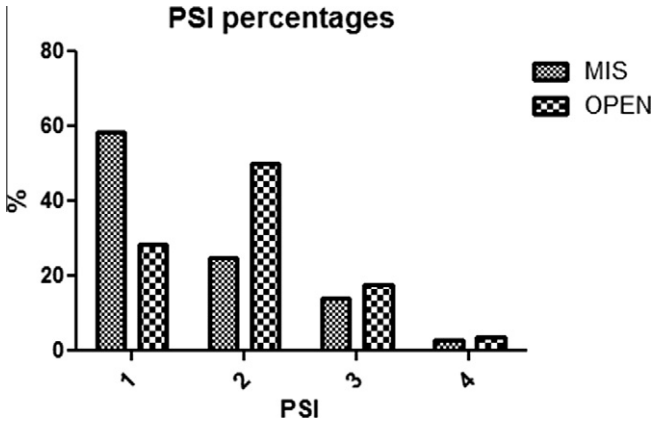

Fig. 4. Graph of the outcomes of the Patient Satisfaction Index (PSI) showing that most patients in both groups had clinically significant improvements; however, those who underwent the minimally invasive spinal (MIS) fusion technique had a greater proportion of patients in Group 1 than did patients from the Open group. PSI outcomes: 1 – surgery met my expectation, 2 – I did not improve as much as I had hoped but I would undergo the same operation for the same results, 3 – surgery helped but I would not undergo the same operation for the same outcome, 4 – I am the same or worse as compared to before surgery).

with bed rest for eight to nine days with no long-term sequelae. Two patients in the open group experienced non-union. This was determined following complaints of worsening mechanical lower back pain at the operation site over 9 to 12 months and significant motion and subsidence on flexion–extension lateral radiographs and CT scans. Subsequent revision surgery was required for both patients. Three patients in the open group also incurred paralytic ileus, determined by postoperative nausea and vomiting. One patient in the open cohort suffered deep vein thrombosis.

4. Discussion

Detachment and retraction of paraspinal muscle and the excessive intraoperative dissection required for open procedures can result in denervation, atrophy and irreversible muscle injury. MIS

Table 4
Results of the Patient Satisfaction Index (PSI) questionnaire for patients who underwent minimally invasive surgery (MIS) compared to open spinal fusion (open).

Option no.	MIS	Open	p
1	21	8	0.0236
2	9	14	0.0650
3	5	5	0.7367
4	1	1	1.0000
Total	36	28	

PSI options: 1 – surgery met my expectation, 2 – I did not improve as much as I had hoped but I would undergo the same operation for the same results, 3 – surgery helped but I would not undergo the same operation for the same outcome, 4 – I am the same or worse as compared to before surgery.

Table 6
Surgical and postoperative complications for patients who underwent minimally invasive surgery (MIS) compared to open spinal fusion (open)

Complication	MIS (no. [%])	Open (no. [%])	p
Screw malposition	0	0	–
Cage migration	0	0	–
Infection*	1 (2.70)	2 (6.67)	0.5829
Haematoma	1 (2.70)	0	1.0000
Dural tear	0	1 (3.33)	0.4478
Non union	0	2 (6.67)**	0.1967
Paralytic ileus	0	3 (10)	0.0848
Deep vein thrombosis	0	1 (3.33)	0.4478
Postoperative radiculopathy	0	1 (3.33)	0.4478
Revision surgery	0	2 (6.67)	0.1967
Complication rate	2 (5.40)	10 (33.33)	0.0040

* Urinary tract infection.
** Patients requiring revision surgery.

approaches attempt to achieve the goals of conventional open surgery and solve the aforementioned problems by minimising the amount of iatrogenic soft tissue injury, by utilising smaller surgical incisions.[6,8,10,13,14,16,17,34] MIS, however, includes the use of imaging for navigation during pedicle screw placement. The use of imaging prolongs operating times, while also increasing patient and surgeon exposure to ionising radiation.[3,35] Furthermore MIS techniques have steep learning curves, requiring a different set of cognitive, psychomotor and technical skills.[6,9,14,18] It is recommended that surgeons have adequate experience with open procedures before attempting MIS methods.[15] Most studies agree that operative times for MIS (90–220 minutes) are significantly longer than conventional open spinal fusion (142–203 minutes), but this depends on surgeon experience.[9,12,13,16,17,36] Intraoperative blood loss in MIS is significantly lower than in conventional open approaches.[3,13,16,36,37]

MIS approaches to spinal fusion have not yet been shown to be superior in effectiveness to traditional open techniques. In our study the ODI and SF-12 questionnaires were utilised to analyse the impact of these surgical techniques on patient disability and quality of life (QoL), and the VAS score was used to assess pain. Both groups showed significant improvements in QoL and reduction in disability following surgery, with the ODI reduced from 54% to 22% for the MIS technique ($p < 0.0001$), and from 52% to 28% for the open technique ($p < 0.0001$). Significant reductions in pain postoperatively were observed following each technique, with the VAS score being reduced from 7.9 to 2.4 for the MIS technique ($p < 0.0001$) and from 8.2 to 3.3 for the open technique ($p < 0.0001$). Postoperative pain was significantly lower following the MIS technique (2.4 compared to 3.3), but despite this, the amount of pain relief (change in VAS score) provided by both procedures was not significantly different. Studies show that clinical outcomes such as pain and disability following spinal fusion improve for 12 months, with little further improvement or even worsening after this point.[38,39] Our results suggest MIS is just as effective as open spinal fusion, similar to other studies.[3,40] However, a study by Kasis[18] comparing PLIF procedures (standard compared to less-invasive) found significantly greater improvements for the less invasive PLIF group.[18] Additionally, with regard to patient satisfaction, measured using the PSI, our results suggest that a significantly greater proportion of patients had their expectations met following the MIS technique (58%) than the open technique (28%). These findings suggest that the MIS approach provides greater patient satisfaction while being as effective, if not more so, than the conventional open approach.

Reducing iatrogenic tissue injury during surgery should theoretically reduce recovery time, time to mobilisation, and length of stay in hospital.[13,40] Our study found that the average length of hospitalisation for the MIS group was 5.89 days (range: 2–20 days), which is significantly shorter than the 9.66 days (range: 3–29 days) required by the open group. Furthermore the average time to begin mobilisation following the MIS technique was 21 hours (range: 12–51 hours), which was again significantly shorter than the open technique, which required 31 hours (range: 12.5–70.5 hours). Similar results have been found in the literature with average length of stay ranging from 2.24 days to 9.3 days compared to 4 days to 10.8 days, and the average time to mobilise ranging from 1.22 days to 3.2 days compared to 2.97 days to 5.4 days for minimally invasive and open techniques, respectively.[13,16–18,36,37,40] These results emphasise the clinical advantages of MIS approaches with regard to recovery, which offset the costs of specialised and expensive equipment, ultimately making it a cheaper option than traditional open spinal fusion.[37,40]

Our study contradicts other studies on MIS techniques in that the complication rate is lower in the MIS group, rather than the open group. The explanation is most likely that the senior surgeon performs a greater number of MIS operations than open procedures. In addition, the senior surgeon has performed over 700 percutaneous pedicle screw insertions and his accuracy is greater using percutaneous techniques than open techniques.

The goal of postoperative pain management is to relieve pain while keeping side effects to a minimum.[23,24,41] The decreased postoperative pain associated with MIS techniques potentially reduces narcotic use, which in turn make the goals of postoperative pain management more easily achievable.[13,40] Our study showed a statistically significant difference in opioid usage between the MIS approach (85 mg) and the open approach (168 mg) suggesting that MIS techniques reduce narcotic use along with their undesirable side effects.

Table 5
Perioperative data for patients who underwent minimally invasive surgery (MIS) compared to open spinal fusion (open)

	MIS	Open	p
Average length of hospital stay (±SD) [median] (days)	5.889 ± 3.133 [5] ($n = 36$)	9.655 ± 6.699 [8] ($n = 29$)	0.0016
Average time to mobilise (±SD) [median] (hours)	21.86 ± 9.833 [18] ($n = 36$)	31.24 ± 15.30 [24] ($n = 29$)	0.0021
Opioids (±SD) [median] (mg of IV morphine)	85.90 ± 109.0 [46.67] ($n = 37$)	168.9 ± 170.6 [103.8] ($n = 26$)	0.0130
Non-opioid analgesia (±SD) [median] (g of paracetamol)	25.81 ± 12.44 [23.00] ($n = 37$)	34.81 ± 25.17 [30.00] ($n = 26$)	0.1176

IV = intravenous, SD = standard deviation.

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Some of the common complications for spinal fusion procedures include hardware malpositioning, deep vein thrombosis, cerebrospinal fluid leak, paralytic ileus, damage to blood vessels and nerve roots, infections, pseudoarthrosis, neurological deficit, haematoma and cardiopulmonary complications.[37,40] Complications with MIS techniques may be more difficult to assess and repair.[13,16,40] Some authors also believe that minimal exposure is also associated with incomplete treatment of pathology,[14] especially considering that bleeding tendencies significantly increase the difficulty of MIS procedures by reducing visualisation.[10] Studies have shown similar total complication rates for the MIS and open approaches.[13,16,40] However, in contrast to previous publications, the complication rate in our study for the MIS technique (5%), which is similar to that reported in the literature (0–19%), was significantly lower than the complication rate for the open technique (33%), which is slightly higher than reported in the literature (16–27%).[40]

4.1. Study limitations

Our current study has limitations including: small sample size, short follow-up time, results influenced by other conditions (for instance, arthritis) and other operations following spinal fusion. Limitations also exist in the method we utilised to compare postoperative analgesia. The equianalgesic doses are rough estimates and remain controversial.[25] By comparing opioid and non-opioid usage separately[31,41,42] our study neglects the synergistic effect of postoperative analgesia. As a way to overcome these limitations, long-term, randomised, prospective studies which use larger sample sizes with longer term follow-up are needed.

5. Conclusion

Spinal fusion remains the gold standard in maintaining the stability of unstable spinal segments for multiple potential pathologies. The MIS technique provides similar efficacy to the conventional open technique, and proves to be superior in regards to patient satisfaction, length of hospital stay, time to mobilise and complication rates provided a good understanding of surgical anatomy is present. As a result it is expected that MIS will become a prominent part of spinal surgery and that indications for MIS fusion will expand.

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