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ORIGINAL ARTICLE - SPINE DEGENERATIVE

Midline lumbar interbody fusion (MIDLIF) with cortical screws: initial experience and learning curve

Fábia Silva [1] · Pedro Santos Silva [1,2] · Rui Vaz [1,2,3] · Paulo Pereira [1,2,3]

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Abstract

Background A variety of surgical techniques can be used to achieve lumbar spinal fusion for management of degenerative conditions. Transforaminal lumbar interbody fusion (TLIF) is the most popular technique; however, midline lumbar interbody fusion (MIDLIF) is a valid alternative to the more traditional pedicle screw trajectory with potential advantages. The aim of this study is to evaluate the clinical outcomes from a cohort of patients submitted to MIDLIF in a single hospital during the surgical team's initial learning period.

Methods The first 30 consecutive patients who underwent single- or two-level MIDLIF surgery for lumbar degenerative disease were included in this retrospective study. Patients' demographics, surgical data, length of hospitalisation, and perioperative complications were analysed. Preoperative and postoperative radiographic parameters were obtained. Validated questionnaires, Core Outcome Measure Index for the back, Euro-QoL 5-Dimensional Questionnaire, and Oswestry Disability Index, were used for clinical assessment.

Results Mean surgery time was 278.53 ± 82.16 min and mean hospitalisation time was 6.17 ± 3.51 days. Six patients experienced complications, four of which being dural tears with no consequences, and two required reoperations during the mean follow-up of 25.23 ± 9.74 months. Preoperative and postoperative radiological parameters did not demonstrate significant differences. All clinical parameters significantly improved after surgery ($p < 0.001$). A complexity score was developed to more accurately compare the different procedures, and it strongly correlated with surgery duration ($r = 0.719$, $p < 0.001$). Furthermore, a moderate correlation was found between a developed Duration Index and the patient's order number ($r = -0.539$, $p = 0.002$).

Conclusions In our initial experience, MIDLIF showed to be effective in significantly improving the patients' functional status, pain scores, and quality of life. The technique seems safe, with an acceptably low complication rate. Hence, MIDLIF can be considered as a promising alternative to more traditional TLIF and PLIF techniques even at the beginning of the learning curve.

Keywords MIDLIF · Midline lumbar interbody fusion · Minimally invasive spine surgery · Lumbar arthrodesis · Cortical bone trajectory screws · Learning curve

Introduction

A variety of surgical techniques can be used to achieve lumbar spinal fusion for management of degenerative conditions such as spondylolisthesis, symptomatic spinal stenosis associated with instability, degenerative disc disease, recurrent disc herniation, and pseudarthrosis. Currently, transforaminal lumbar interbody fusion (TLIF) and posterior lumbar interbody fusion (PLIF) are two of the most popular techniques, but each has its own list of advantages and drawbacks. Also, there is still not enough evidence to claim superiority of a particular technique over each other, even when comparing interbody fusion with posterolateral fusion [6, 9, 18].

Midline lumbar interbody fusion (MIDLIF) is a relatively new method that consists of a posterior midline approach, microsurgical neural decompression, discectomy, interbody fusion, and internal fixation with pedicle screws using a cortical bone trajectory. It is a valid alternative to the more traditional pedicle screw trajectory and one of the potential advantages is a lower

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✉ Fábia Silva
fabia.natacha@gmail.com

[1] Faculty of Medicine, University of Porto, Al. Prof. Hernâni Monteiro, 4200-319 Porto, Portugal

[2] Department of Neurosurgery, Centro Hospitalar Universitário de São João, Porto, Portugal

[3] Neurosciences Center CUF, Porto, Portugal

incidence of nerve root damage, due to the medial to lateral screw trajectory in the axial plane. A further benefit of this technique comparing with a traditional open approach is a smaller incision and less retraction of the paraspinal muscles, which may translate in less postoperative pain and use of analgesics, earlier mobilisation, and decreased blood loss. Comparing with other minimally invasive techniques, MIDLIF allows to obtain decompression and spinal fixation through a single incision [4, 15]. Nonetheless, some potential disadvantages may arise when implementing a new procedure, such as longer operative times and possibly a higher rate of complications, more prominently in the beginning of the learning curve.

The aim of this study is to assess the clinical outcomes from an unselected cohort of consecutive patients who underwent a MIDLIF surgery in a single hospital during the surgical team's initial learning period.

Methods

Study design and inclusion criteria

This is a consecutive case series with retrospective compilation of prospectively collected data of patients who underwent MIDLIF surgery at a Portuguese tertiary hospital (Department of Neurosurgery of Centro Hospitalar Universitário de São João) from February 2015 to March 2018. Inclusion criteria were patients over 18 years old with an indication for lumbar fusion at one or two levels due to a degenerative condition, in addition to neural decompression at the fusion levels, with or without a need for decompression at adjacent levels. Indications for surgery included degenerative spondylolisthesis, degenerative disc disease, isthmic spondylolisthesis, and spinal canal and/or foraminal stenosis. Revision surgeries were also included. Routine follow-up consultations were scheduled at 1, 6, and 12 months after surgery. Additional appointments were scheduled as needed. Postoperative Patient-Reported Outcome Measurements (PROMs) were collected at the 12-month consultation. On March 2019 (mean 25.23 months after surgery), all patients were contacted by phone and questioned about late complications and revision surgeries. For this study, we analysed postoperative PROMs [20] and compared them with preoperative data to evaluate the improvement achieved with surgery. All patients had at least one of the following symptoms: low back pain, radicular pain, radiculopathy, or neurogenic claudication. All data were treated anonymously, and the entire study protocol was approved by the hospital's ethics committee.

Surgical technique

MIDLIF technique has been described in detail in previous literature [1, 8, 15]. Shortly, after placing the patient in prone position, a midline skin incision is made, bilateral paraspinal muscle dissection is performed, and a self-retaining lumbar retractor system with illuminated divergent blades is placed. We perform flavectomies, inferior laminotomies, and facetectomies bilaterally as needed to decompress the thecal sac, traversing and exiting nerve roots. A standard microdiscectomy, followed by endplates preparation, is carried out. Then, 1 or 2 bullet-shaped PEEK cages filled with local bone chips are inserted in the disc space and the remaining bone chips are placed in front and around the cage. The starting point for cortical screw insertion is identified on the pars interarticularis and screws are placed under fluoroscopic guidance using a cortical bone trajectory from medial to lateral and caudal to cranial. CD Horizon® Solera™ cortical fixation multiaxial screws (Medtronic Sofamor Danek, USA) with 4.5-mm diameter and lengths ranging from 25 to 35 mm have been used. The final construct is completed with prebent 4.75 mm chromium-cobalt rods.

Radiographic measurements

The following radiographic parameters were measured on preoperative and postoperative spinal X-rays and compared lumbar lordosis (LL), pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and sagittal vertical axis of C7 (SVA). One-year postoperative CT scan was used to evaluate fusion.

Clinical and functional outcome measurements

The clinical outcome was assessed using the following questionnaires: Core Outcome Measures Index for the back (COMI-back), including a back pain and buttock/leg pain numeric rating scale (back NRS and leg NRS, respectively), Euro-QoL 5-Dimensional Questionnaire (EQ-5D), and Oswestry Disability Index (ODI) [7, 13, 22]. According to the literature, minimal clinically important difference (MCID) was considered as a minimum change from preoperative to postoperative scores of 1.7 points for COMI-back, 12.8 for ODI, and 0.30 for EQ-5D [3, 5, 21]. The entire information was obtained through patients' clinical records and the EUROSPINE international spine registry (Spine Tango).

Statistical analysis

Shapiro–Wilk and Kolmogorov–Smirnov normality tests were used to access normality distribution of continuous variables. Preoperative and postoperative clinical variables and radiological parameters were compared using paired samples *t* test. Pearson correlation coefficient was used to measure the association between continuous variables. Categorical data were analysed in contingency tables with Fisher's exact test. IBM SPSS Statistics version 24.0 software was utilised for statistical analysis.

Results

A total of 30 patients were included in the study, of which 24 (80%) were women. At the moment of surgery, the mean age was 66.3 ± 8.6 years. Two patients (6.7%) were smokers and the mean body mass index (BMI) was 29.70 ± 3.93 kg/m^2. Mean surgery time was 278.53 ± 82.16 min, with 62.92 ± 27.78 s of mean fluoroscopic exposure. Six patients (20%) experienced complications, four (66.7%) of these being dural tears repaired during surgery, without cerebrospinal fluid leak or any consequence in the postoperative period. Mean length of hospital stay was 6.17 ± 3.51 days and the mean follow-up was 25.23 ± 9.74 months, ranging from 12 to 47 months. Two patients (6.7%) required reoperation: a wound debridement for infection and a revision surgery for additional decompression, 17 months after the MIDLIF procedure. Further demographic and surgical data of the cohort are presented in Tables 1 and 2.

All clinical parameters, namely, back and leg NRS, ODI, EQ-5D, and COMI scores, significantly improved after surgery (Paired t test, $p < 0.001$) (Table 3). MCID was achieved in 69.2% of the patients regarding EQ-5D, 65.4% for COMI-back, and 50% for ODI. When considering the MCID for COMI-back, 89% of patients who were not taking antidepressants as part of their daily medication achieved a successful outcome, as opposed to 14% of subjects diagnosed and treated for depression (Fisher, $p < 0.001$). Radiological parameters did not change significantly after surgery (Table 3). Only one patient did not present criteria for interbody fusion in postoperative CT scan, namely continuous bone bridging across the disc space; hence, the fusion rate at 12 months was 96.7%. No patient had clinical complaints or required reoperation because of pseudarthrosis. No patient presented with new radicular symptoms or neurological deficits in the postoperative period and no patient was reoperated because of misplaced, fractured, or loosened screws.

Since it is difficult to directly compare surgeries with different extents of decompression and fixation, a complexity

Table 1 Patients' demographics and past medical history

	Patients, no. (%)
Work status before/after surgery	
Employed	5 (16.7)/3 (10)
Unemployed	2 (6.7)/4 (13.3)
Retired	21 (70)/22 (73.3)
Sick leave	2 (6.7)/1 (3.3)
Past medical history	
Diabetes mellitus	7 (23.3)
Hypertension	20 (66.7)
Dyslipidemia	16 (53.3)
Obesity	15 (50)
Rheumatological disease	12 (40)
Psychiatric disease	7 (23.3)
Cardiac disease	5 (16.7)
Thyroid disease	4 (13.3)
Peptic ulcer disease	3 (10)
Chronic pulmonary disease	2 (6.7)
Cervical myelopathy	1 (3.3)
Medication	
Paracetamol	11 (36.7)
NSAIDs	14 (46.7)
Opioids	9 (30)
Pregabalin	5 (16.7)
Antidepressants	7 (23.3)
Previous surgeries	
Lumbar Surgery	8 (26.7)
Cervical Surgery	2 (6.7)

NSAIDs non-steroidal anti-inflammatory drugs

Table 2 Surgical data

	Patients, no. (%)
Primary surgical indication	
Degenerative SPL	20 (66.7)
Isthmic SPL	2 (6.7)
Central + foraminal stenosis	2 (6.7)
Revision surgery	6 (20)
Zone/cause of neural compression	
Central stenosis	29 (96.7)
Foraminal stenosis	4 (13.3)
Lateral recess stenosis	5 (16.7)
Disc herniation	2 (6.7)
Additional levels of decompression, apart from fusion level(s)	
1 level	6 (20)
2 levels	1 (3.3)
3 levels	1 (3.3)
Levels of fixation	
L2-L3	1 (3.3)
L3-L4	1 (3.3)
L4-L5	16 (53.3)
L5-S1	2 (6.7)
L2-L3 + L3-L4	1 (3.3)
L3-L4 + L4-L5	7 (23.3)
L4-L5 + L5-S1	2 (6.7)
Estimated intraoperative blood loss (mL)	
< 100	6 (20)
100–500	24 (80)
Intraoperative and postoperative complications	
Dural tear	4 (13.3)
Wound infection	1 (3.3)
Respiratory insufficiency	1 (3.3)

SPL spondylolisthesis

Table 3 Clinical and radiological outcomes

	Preop	Postop	*p* value
PROMs			
COMI-back	8.40 ± 1.34	4.84 ± 3.25	< 0.001
Back NRS	7.00 ± 3.09	3.85 ± 3.09	< 0.001
Leg NRS	8.12 ± 2.72	3.420 ± 3.89	< 0.001
EQ-5D	0.07 ± 0.31	0.52 ± 0.45	< 0.001
ODI	60.15 ± 20.19	40.81 ± 29.28	< 0.001
Radiological parameters			
LL	52.31 ± 12.67	51.29 ± 13.98	0.480
PT	21.22 ± 9.04	20.03 ± 9.99	0.310
PI	52.63 ± 14.32	50.56 ± 12.22	0.134
SS	31.41 ± 14.96	30.53 ± 14.53	0.546
SVA	3.39 ± 7.67	2.64 ± 3.32	0.689

Preop preoperative, *Postop* postoperative

score was developed to try to overcome this issue. For each nerve root decompressed, 0.5 points were given, plus 1 point for every level of central canal decompression and 2 points for each level of fixation. The mean complexity score obtained was 5.73 ± 2.07, varying from 3 to 10. A strong correlation was found between mean surgery time and the developed complexity score (Pearson, $r = 0.719$, $p < 0.001$). To adjust the duration of surgery to the number and type of surgical steps performed, we created an index (Duration Index, DI), dividing surgery time by the complexity score. A moderate correlation was found between this index and the patients' case number (Pearson, $r = -0.539$, $p = 0.002$), confirmed by a linear regression analysis (R^2, 0.3; $p = 0.002$) (Fig. 1). The complexity score also correlated with the length of hospital stay (Pearson, $r = 0.45$; $p < 0.014$). There were no significant differences between preoperative and postoperative radiological parameters.

Discussion

Previous studies have advocated for the non-inferiority of MIDLIF comparing with other surgical techniques in achieving lumbar spine decompression and fusion for a variety of clinical indications. Cortical bone trajectory screws have been related to improved fixation in osteoporotic bone and a lower risk of injury to the neural elements. Furthermore, in recent studies, MIDLIF has been reported to reduce operation time and postoperative pain comparing with more traditional approaches like TLIF and PLIF [4, 15, 16]. However, as for any new procedure, longer operative times and potentially an increased complication rate can be expected in the beginning of the learning curve. Hence, the anticipated advantages and drawbacks of any new technique must be carefully weighed. With this in mind, we decided to analyse the clinical and radiological results of the initial cohort of patients who underwent a MIDLIF procedure in our hospital, performed by a single surgeon. Our main indication for MIDLIF was patients with severe spinal canal and foraminal stenosis, with or without spondylolisthesis, where extensive bilateral facetectomies were considered indicated. We also performed this technique to achieve neural decompression and fusion and additional decompression at adjacent levels, where a midline approach was considered appropriate. Revision surgeries were included, when there was a need to decompress and fuse levels adjacent to previously instrumented ones, because MIDLIF allowed to insert additional rods connected to the previous ones, obviating the need to expose all the instrumentation and remove the rods. Lastly, MIDLIF was favored in osteoporotic patients, since the screws with cortical purchase were considered a potential benefit.

When compared with other MIDLIF series published in the literature, our mean surgery time was superior, which might be due to the variety of surgical indications and number of levels decompressed and fused in the present study, which intuitively affects surgery duration. Our complexity score supports this assumption, by having a statistically significant relation with mean surgery time, which in turn holds that the parameters used to formulate this score are appropriate. In addition, 26.7% of our patients had previous lumbar surgeries, which is a well-known factor contributing to an increase in surgical duration. Other publications on MIDLIF surgery include, in general, a smaller cohort, somewhat younger patients and more limited surgical indications. Our mean operative time showed to be related with surgery's complexity and surgeon's experience. Our abovementioned Duration Index decreased as more surgeries were performed. The line plotted in Fig. 1 may represent the initial phase of a learning curve, fitting a straight line instead of a negative exponential curve due to the small number of cases. Articles about learning curve for minimally invasive TLIF state that it flattens after 30 to 40 cases [11, 19]. Hence, it seems reasonable to assume that the proficiency level is about to be reached in our series and duration of surgery will tend to an asymptote in the upcoming cases.

In our series, surgical complexity, and subsequently mean operative time, seems to predict length of hospital stay. This can be one of the reasons why our mean hospital stay (6.17 days) was about 3 days longer than most MIDLIF studies [1, 6, 8, 15–17]. Nevertheless, Bielecki et al. [1] reported a mean hospital stay (6.2 days) similar to ours, despite a 50-min shorter average surgery time (228 min) and the non-existence of intraoperative complications; however, their case series included only 5 patients. Moreover, length of stay is more commonly influenced by institutional routine standards than by surgical variables themselves, so it is difficult to compare these data among centres.

Dabbous et al. [4] reported the first MIDLIF prospective case series published in Europe, including 25 patients. In their

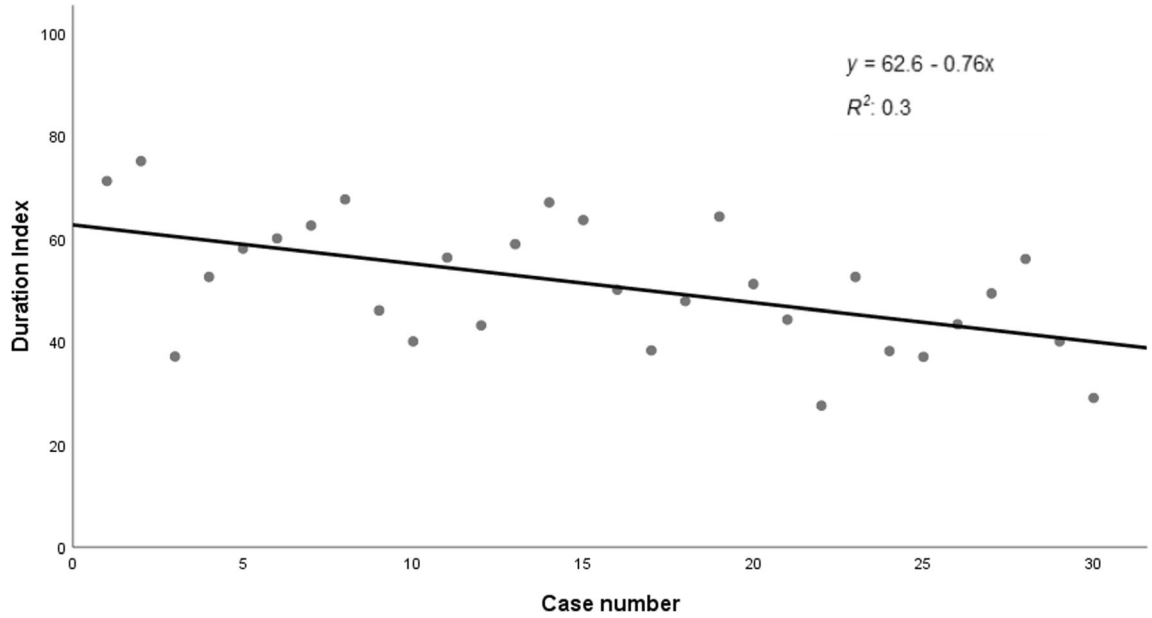

Fig. 1 Initial learning curve for 1–2 levels MIDLIF as shown by Duration Index

study, mean postoperative improvement in ODI is similar to our series' and other previous reports [1, 8]. Likewise, our study demonstrated similar improvements in every other PROM included, supporting the effectiveness of the surgical technique. Also, this seems to be a fairly safe procedure. Dural tears are among the most common complications of lumbar spine surgery, particularly in cases of severe spinal stenosis and revision surgeries [2]. In our series, they occurred in 13% of the patients, but none had consequences in the postoperative period. Cage migration, pedicle fracture, and screw loosening have been reported in previous studies [4, 6, 15].

MIDLIF's aim is not to correct spinal deformity, so it is not surprising that there were no significant changes in sagittal alignment parameters after surgery in our results. In line with the literature, in our series, patients with less postoperative lumbar lordosis had worse clinical outcomes [10, 12], which raises the issue that those patients may benefit more from other techniques designed to increase lumbar lordosis, such as posterior osteotomies or lateral approaches.

Of all demographic and disease-related variables, use of antidepressants was the only one to somehow predict clinical outcome. In this study, patients with depression had mostly unsatisfactory postoperative outcomes in terms of pain, disability, and quality of life. This is in line with several other studies in which depressive symptoms negatively influence the outcome after spinal surgery. These findings reiterate the need to identify and properly manage this subgroup of patients, before considering them as surgical candidates [14, 23].

The small size of the cohort is a limitation of the present study that may have an influence in the reported results. Moreover, the broad inclusion criteria hinder stronger conclusions but, on the other hand, this series may represent the application of MIDLIF technique to a 'real world' population of patients needing lumbar fusion. Additionally, in some patients, their ability to fully understand and correctly answer the questionnaires may be questionable. Even though these questionnaires are considered cognitively undemanding, some patients have difficulties understanding the differences between the various levels of severity of symptoms or functional incapacity; this seems to be particularly true for older and less educated patients. The long surgery durations also reflect the challenges of introducing a novel technique. Still, the results presented in this study showed to be promising. Multicentre studies with larger cohorts are essential to increase confidence on the results and to evaluate the generalisability of the MIDLIF technique. Also, larger studies are an opportunity to report less frequent complications, but possibly more serious ones.

Conclusions

In our initial experience, MIDLIF significantly improved the patients' functional status, pain scores, and quality of life. For the moment, the technique seems to be safe, with an acceptably low complication rate. Hence, MIDLIF can be considered as a promising alternative to more traditional TLIF and PLIF techniques, but further studies are necessary to define the ideal indications, evaluate the learning curve, and estimate the effect sizes and safety profile.

Compliance with ethical standards

Conflict of interest PP has an education and training and consultancy agreement with Medtronic Sofamor Danek, USA. FS, PSS, and RV certify that they have no affiliations with or involvement in any organisation

or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements) or non-financial interest (such as personal or professional relationships, affiliations, knowledge, or beliefs) in the subject matter or materials discussed in this manuscript.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee (Comissão de Ética para a Saúde do Centro Hospitalar Universitário de São João) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

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