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ORIGINAL ARTICLE

Higher risk of dural tears and recurrent herniation with lumbar micro-endoscopic discectomy

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Abstract Existing studies on micro-endoscopic lumbar discectomy report similar outcomes to those of open and microdiscectomy and conflicting results on complications. We designed a randomised controlled trial to investigate the hypothesis of different outcomes and complications obtainable with the three techniques. 240 patients aged 18–65 years affected by posterior lumbar disc herniation and symptoms lasting over 6 weeks of conservative management were randomised to micro-endoscopic (group 1), micro (group 2) or open (group 3) discectomy. Exclusion criteria were less than 6 weeks of pain duration, cauda equina compromise, foraminal or extra-foraminal herniations, spinal stenosis, malignancy, previous spinal surgery, spinal deformity, concurrent infection and rheumatic disease. Surgery and follow-up were made at a single Institution. A biomedical researcher independently collected and reviewed the data. ODI, back and leg VAS and SF-36 were the outcome measures used preoperatively, postoperatively and at 6-, 12- and 24-month follow-up. 212/240 (91%) patients completed the 24-month follow-up period. VAS back and leg, ODI and SF36 scores showed clinically and statistically significant improvements within groups without significant difference among groups throughout follow-up. Dural tears, root injuries and recurrent herniations were significantly more common in group 1. Wound infections were similar in group 2 and 3, but did not affect patients in group 1. Overall costs were significantly higher in group 1 and lower in group 3. In conclusion, outcome measures are equivalent 2 years following lumbar discectomy with micro-endoscopy, microscopy or open technique, but severe complications are more likely and costs higher with micro-endoscopy.

Keywords Lumbar disc herniation · Discectomy · Microdiscectomy · Micro-endoscopic discectomy

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Introduction

Surgical discectomy for lumbar disc herniation (LDH) provides effective relief for selected patients with sciatica not resolving with conservative management, but the choice of micro or standard discectomy at present depends more on the training and expertise of the surgeon, and the resources available, than on scientific evidence of efficacy [6]. Randomised trials need to be improved on the issues of sufficient power, adequate randomisation, blinding, duration of follow-up and clinical outcome measures. There are major gaps in our knowledge on the costs of all forms of surgical treatment of lumbar disc prolapse [8], with a need for better evidence on the relative clinical outcomes, morbidity and costs of micro versus standard discectomy [6]. The evolution of surgery for LDH has aimed at addressing the pathology while minimising the surgical morbidity since Caspar [4] in 1977 described the lesser invasive concept of microsurgical discectomy (MD) as opposed to Love's [10] open discectomy (OD). Microdiscectomy gained progressive popularity, as it achieved an equivalent success rate to open discectomy, with a reported reduction in surgical morbidity reflected into shorter hospitalisation and earlier return to work [3, 4, 18, 19]. In the meantime, the enthusiasm surrounding minimally invasive techniques in spinal surgery resulted in the evolution of various percutaneous procedures, including

chemonucleolysis [22], percutaneous lumbar nucleotomy [13] and discectomy [15] and laser discectomy [5]. None of these methods has proven the same efficacy as OD or MD [6]. In 1997, Foley and Smith [17] described micro endoscopic discectomy (MED) as a new percutaneous technique and in 2002 reported on their first established results. Despite a steep learning curve, bi-dimensional view and higher costs, several authors have reported on the reliability of this new technique in retrospective series [2, 14], but a randomised clinical trial comparing MED with OD did not find significant differences in the main outcome indexes [20]. Meanwhile, MD and OD analysed in a prospective comparative study showed similar clinical outcomes [11], while MED and MD compared in another prospective comparative study behaved similarly [22].

Therefore, the aim of this project was to test the hypothesis that at a minimum follow-up of 2 years MED, MD and OD would provide different outcomes—visual analogue scores (VAS) for back and leg, Oswestry disability index (ODI) and short form 36 (SF36)—and complication rates after randomising patients affected by LDH at a single tertiary referral Institution for spinal disorders.

Materials and methods

Admission criteria and recruitment of patients

Inclusion criteria to enter the study were a diagnosis of symptomatic, single level posterior lumbar disc herniation (LDH) made by spine specialists (orthopaedic and neurosurgeons) in patients aged 18–65 years with pain and/or neurological signs in concordant distribution lasting at least over 6 weeks of appropriate conservative treatment consisting of systemic drugs for pain relief and/or epidural steroid administration [3, 6, 11, 18, 20, 21, 23]. Exclusion criteria were less than 6 weeks of pain duration, cauda equina symptoms, foraminal or extra-foraminal herniations, cervical or lumbar spine stenosis of any aetiology, malignancy, previous spine surgery, spinal deformity including spondylolisthesis of any aetiology, concurrent infection and rheumatic disease [3, 6, 11, 18, 20, 21, 23]. Patients were seen as outpatient referrals or acute admissions to the Accident and Emergency Department of a tertiary referral Orthopaedic and Neurosurgical Institute. Diagnosis and level of the single lumbar disc herniation were confirmed by musculoskeletal radiologists from the same institute with either a non-contrast 1.5-Tesla MRI or a CT scan of the lumbar spine, supplemented with plain X-rays of the lumbar spine including the thoracolumbar tract to exclude or confirm the presence of a segmentation anomaly [3, 6, 11, 18, 20]. The type of posterior disc herniation was rated as protrusion, extrusion and sequestration as per usual grading on either CT or MRI images [3, 6, 11, 18, 20, 21], and pertinent data were inserted into the database of the three treatment groups. Adverse events, i.e. complications, included: death, wound infection, disc infection (spondilodiscitis), dural injury, root injury, recurrence of herniation and worsening of motor deficits [3, 6, 11, 18, 20, 21, 23]. Patients were enrolled in the first month of the year 2007. The local ethical committee expressed approval of the study with the caveat that blindness had to be omitted "in order to protect the possibility of a free choice for patients" (sic). Computer-aided randomisation to MED (group 1), MD (group 2) or OD (group 3) was used with the above criteria in patients who were willing to participate and gave their informed consent. According to the indications of the ethical committee, group assignment was revealed to patients prior to the surgical operation [12].

Surgical technique

All patients were operated under general anaesthesia in the knee–chest prone position in order to lower the chance of epidural bleeding [19]. This effect was further aided by hypotensive anaesthesia, use of cotton patties and bipolar electrocautery. The surgeons who accepted to be part of the study worked in close cooperation within the spinal department of a single Institution, and had a longer than 5 years experience with the use of MED and a longer than 10 years experience with the use of MD and OD at the start of study. This aimed at limiting the bias effect of a long surgical learning curve, especially correlated with MED [2, 14, 17, 20, 21]. In group 1, the Metr'X system (Medtronic Sofamor Danek, Memphis, USA) with a 16- or 18-mm tubular retractor was used. In groups 2 and 3, a Caspar retractor was used to obtain direct vision of the operative field, with the obvious difference that in group 2 a surgical microscope was used, while in group 3 magnifying loops were used as needed [3, 5, 9, 15–17]. The surgical technique did not differ from what has already been published on MED, MD and OD for the treatment of LDH [2, 3, 5, 7, 9, 14–17, 19]. Laminotomy, medial facetectomy when needed and nerve root retraction followed by discectomy were all performed identically in the three groups [2, 3, 6, 11, 17, 18, 20, 21, 23].

Design of the study

A retrospective pilot study made at the same Institution and comparing the results of MED and MD for lumbar disc herniation indicated a drop-out figure of 10% and suggested a sample dimension of 70 cases per arm (MED, MD and OD) which was calculated upon consideration of VAS at 24-month follow-up as the main quantitative outcome

variable. The sample size of 70 plus 10% (77) subjects per treatment arm was obtained by using a dedicated software [6] and calculated assuming a type 1 error (α) two-tailed = 0.05 and a type II error (β) = 0.20, hence a test power of 80% ($1 - \beta = 0.80$) and a standard deviation (SD) in the VAS scale of 3.8. We considered 1.5 points or 30% of the baseline score as minimal clinically important difference (MCID) within treatment groups between preoperative and follow-up VAS (0–10 cm) scores, and a MCID of 10 points or 30% of the baseline in ODI and SF-36 scores [1, 24]. Missing data were managed in the following way: for the postoperative assessment, values were calculated by using the patient's preop value and assuming the same change from preoperative to postoperative as for the whole group (or if the preop value was missing but the postoperative value was available); at all other follow-ups the last value was moved forward [9, 12].

Management of outcome data

As detailed in Table 2, back and leg VAS scales and ODI 2.0 plus SF36 questionnaires [1, 12, 24] were obtained before surgery (preoperative), at the first follow-up after 10 days from surgery (postoperative), and subsequently at 6, 12 and 24 months after the index surgery. Data from those patients who were re-operated for recurrences were put into those of the original groups as per an intention to treat analysis [9, 12]. Patients normally completed the questionnaires at home, but for those follow-ups associated with a hospital visit (pre- and postoperative) patients were asked to fill in the questionnaires at the time of their appointment; otherwise (6, 12 and 24 months) they returned the questionnaires by mail. Questionnaires were checked and any missing or unclear parts were returned to patients for revision. Secretarial personnel not involved in the patients' care contacted non-responders during follow-up until the questionnaire was returned or the patient made clear that no questionnaire would be returned [12].

Analysis of costs

The cost of MED equipment was the sum of the cost of the dedicated decompression and suction tools (15,000 Euros in the European Community market at the time of writing) plus the cost of the endoscope, video integrator and monitor (15,000 Euros) and finally the cost of the disposable connectors for the video camera (300 Euros per case). Comparatively, the cost a standard set of Caspar retractors plus laminotomy and discectomy tools reaches 10,000 Euros. In the case of MD, the cost of a surgical microscope has to be added (10,000 Euros) while head-on magnifying loops were purchased (2,000 Euros) to perform ODs. As a consequence, for the entire duration of the study (77 cases per arm) the cost for the surgical instrumentation summed up to 53,000 Euros for MED (688 Euros per case), 20,000 Euros for MD (260 Euros per case) and 12,000 Euros for OD (155 Euros per case). In order to obtain the hospital costs, we added to these sums the costs of operating room times (1,200 Euros per hour in our Institution), of fibrin glue (1 ml kit costing 1,200 Euros) in case of dural repair, of hospitalisation with a cost of 450 Euros/24 h at the time the study was being carried on, and of re-operations when performed for recurrent prolapses.

Results

Cohort and group results

A total of 240 patients were enrolled and 212 (139 males and 73 females, ratio = 1.9:1) with a mean age at surgery of 39.3 years (range 27–61) completed the 24-month follow-up period (91%). 24 patients (7%) were dropped-out because of being non-respondents or incomplete respondents despite repeat solicits and five (2%) were unhappy with the results of treatment and refused to participate further. The cohort follow-up averaged 26 months (range 24–29). By the end of the 24-month follow-up, 15 patients (7%) had undergone reoperations: 13 (6%) for recurrences of LDH and 2 (1%) for repair of pseudomeningocele. They are analysed within the original groups according to the fact that they were treated with the original technique and to an intention to treat analysis [9]. Table 1 displays the demographics of the three treatment groups including levels and type of disc herniation. No variables were significantly different among groups that were as a consequence deemed comparable. In the study cohort (212 patients), back pain and sciatica were present in 159 (75%) and sciatica only in 53 (15%) patients. The duration of pain averaged 12 weeks (range 6–20). At observation, motor weakness was present in 121 patients (57%) and sensory deficit in 190 (90%). Hypoesthesia of the S1 dermatome was recorded in 123 (58%) patients, of the L5 dermatome in 75 (40%) and of the L4 dermatome in 4 (2%). On plain X-rays of the lumbosacral spine a segmentation defect was observed in four cases (2%), straightening of the lumbar spine in 206 (97%) and sciatic list in 112 (53%). Table 1 also displays the level and type of disc herniation that were significantly more prevalent extrusion-type L5–S1 prolapses in the cohort ($p = 0.03$). After stratification per group, these figures were not statistically different, and the groups were deemed comparable. Average surgical time measured from skin incision to skin closure was significantly longer in group 1 (56 ± 12 min, $p = 0.023$) compared to group 2 (43 ± 8 min, $p = 0.062$) and 3 (36 ± 10 min, $p = 0.013$, shortest). The length of the surgical scar at the incision site

Table 1 Patients' demographics (mean ± SD), level and type of lumbar disc herniation (LDH)

	Group 1	Group 2	Group 3	*p*
Age (years)	39 ± 12	40 ± 12	39 ± 12	0.89
Follow-up (months)	26 ± 2	26 ± 3	26 ± 2	0.91
Sex (M:F)	45:25	48:24	46:24	0.92
Duration of pain (weeks)	11 ± 5	12 ± 6	11 ± 5	0.85
Level of LDH	L3/4: 1 (0.7%)	L3/4: 2 (2.9%)	L3/4: 1 (0.7%)	0.75
	L4/5: 29 (42%)	L4/5: 28 (39%)	L4/5: 28 (40%)	0.80
	L5/S1: 40 (57%)	L4/S1: 42 (58%)	L4/S1: 41 (59%)	0.63
Type of LDH	Protrusion: 7 (10%)	Protrusion: 8 (11%)	Protrusion: 8 (12%)	0.88
	Extrusion: 42 (60%)	Extrusion: 42 (58%)	Extrusion: 43 (62%)	0.96
	Sequestration: 21(30%)	Sequestration: 22(31%)	Sequestration: 19(26%)	0.69
Number of cases	70	72	70	0.80

Table 2 Outcome measures (mean ± SD)

	Group 1	Group 2	Group 3	*p*
VAS, leg (preop/postop/6 months/1 year/ 2 years)	8 ± 1/3 ± 1/2 ± 1/1 ± 1/2 ± 1	8 ± 1/3 ± 1/2 ± 1/1 ± 1/2 ± 1	8 ± 1/3 ± 1/2 ± 1/1 ± 1/2 ± 1	0.73
VAS, back (preop/postop/6 months/1 year/ 2 years)	3 ± 1/1 ± 1/2 ± 1/1 ± 1/2 ± 1	4 ± 1/1 ± 1/2 ± 1/1 ± 1/2 ± 1	3 ± 1/2 ± 1/1 ± 1/1 ± 1/1 ± 1	0.75
ODI 2.0 (preop/postop/6 months/1 year/ 2 years), %	40 ± 4/15 ± 5/12 ± 4/14 ± 4/14 ± 6	41 ± 4/13 ± 5/12 ± 4/13 ± 4/16 ± 5	39 ± 4/14 ± 5/12 ± 4/13 ± 4/15 ± 3	0.81
SF36: physical health (preop/postop/6 months/ 1 year/2 years)	20 ± 4/45 ± 5/42 ± 4/44 ± 4/39 ± 6	21 ± 4/43 ± 5/42 ± 4/45 ± 4/40 ± 6	22 ± 4/41 ± 5/42 ± 4/44 ± 4/38 ± 6	0.68
SF36: mental health (preop/postop/6 months/ 1 year/2 years)	22 ± 3/39 ± 3/38 ± 4/40 ± 4/38 ± 5	21 ± 2/40 ± 5/40 ± 4/40 ± 4/39 ± 6	23 ± 2/41 ± 5/40 ± 3/42 ± 3/39 ± 3	0.78

was measured at follow-up, averaging 10 mm in group 1 ($p = 0.002$, shortest), 22 mm in group 2 and 23 mm in group 3 (difference between groups 2 and 3: $p = 0.122$). Outcome variables are summarised in Table 2. VAS scales for back and leg did not show significant differences among groups throughout follow-up, nor did ODI and SF36 scores. VAS, ODI and SF36 scores all improved significantly within groups and showed a higher than MCID (30%) [24] between pre- and postoperative scores that was maintained through follow-up. SF36 scores are summarised into the two sections of physical and mental health for each group; means for the reference population of the country where the study took place are 49 and 49, respectively [1]. Hospital stays averaged 54 ± 12 h in group 1 ($p = 0.021$), 49 ± 9 h in group 2 and 49 ± 10 h in group 3. This figure reflected our prescription of 24 h of observation in hospital after a dural repair had to be performed. If they were allowed the choice of treatment, more patients would have chosen to be in group 1 (53%) than group 2 (34%) or 3 (23%) before being operated on. In contrast, the majority (86%) of those who reached the final follow-up were satisfied when they knew which group they had been randomised to [12].

Adverse events

Complications (Table 3) affected all groups. Dural tears, recurrent herniations requiring surgical treatment and iatrogenic root injuries were significantly more prevalent in group 1 compared to groups 2 and 3. Dural tears were repaired with fibrin glue only in the MED group and with direct suture plus fibrin glue in the other two groups [2, 14, 18]. No patients with dural tears in the MED group developed cerebrospinal fluid (CSF) fistulas requiring revision surgery, while one patient in each of the other groups required secondary repair of a pseudomeningocele. Recurrent (ipsilateral and at the same operated level) herniations were initially treated conservatively as per primary cases [18], but only those that required surgery for the control of pain was input into the analysis of data. Surgical recurrences happened after a mean time from the index procedure of 15 ± 6 weeks in group 1 ($p = 0.071$),

Table 3 Complications: types and rates (mean ± SD)

	Group 1 (%)	Group 2 (%)	Group 3 (%)	*p*
Death	–	–	–	–
Dural tear	6/70 (8.7)	2/72 (2.7)	2/70 (3)	0.37
Root injury	2/70 (3)	0/72 (0)	0/72 (0)	0.45
Recurrent herniation (operated)	8/70 (11.4)	3/72 (4.2)	2/70 (3)	0.39
Wound infection	–	4/72 (5.5)	3/72 (4.2)	0.29
Spondilodiscitis	1/70 (1.4)	–	–	0.56
Worsening motor deficit	2/70 (1.4), permanent	1/72 (1), partial recovery	–	0.47

24 ± 8 weeks in group 2 and 29 ± 12 weeks in group 3 ($p = 0.122$). Those patients affected by recurrences who required surgical treatment were addressed with the same technique used for the primary discectomy, and follow-up clinical data were collected according to an intention to treat analysis [9, 17, 18]. No difference in the outcome variables was found at follow-up after stratifying cases treated for recurrent herniations, whether surgically or conservatively. Wound infections only affected groups 2 and 3 (4/72, 5.5% and 3/72, 4.2%, $p = 0.072$) and were treated with a course of oral antibiotics until resolution. There was a single case (1.4%) of spondilodiscitis in group 1 in one of the patients who suffered an early recurrent herniation that needed a revision MED after 2 weeks from the index procedure. The patient chose to be treated at a different institution with i.v. and oral antibiotics for a period of 3 months until pain improved. She agreed to send the 6 months questionnaires but refused to be contacted further. Her data were included in group 1 and moved forward to the 12- and 24-month follow-up [12]. Finally, two cases of worsening motor deficits that corresponded to cases of root injuries were observed in group 1 and one case in group 2. Only the latter case showed signs of incomplete recovery at follow-up (Table 3).

Analysis of costs

The final costs of LDH surgery in the groups when operating room times, fibrin glue kits and new hospitalisations were added to the direct surgical costs described in "Materials and methods", averaged 3,010 ± 450 Euros per case in group 1 ($p = 0.002$, highest), 2,450 ± 340 Euros per case in group 2 and 2,310 ± 260 Euros per case in group 3 ($p = 0.012$, lowest). These figures are quite consistent with the fixed reimbursement rate of 2,700 Euros the National Health System was providing to cover hospital and personnel costs for primary and revision lumbar disc herniation surgeries. At our Institution, the personnel costs could be quantified for the surgical team for the anaesthesiology team as 10 and 5% of the above figure, respectively.

Discussion

Main findings

In the present randomised study, which is the first to compare three common surgical techniques for the treatment of LDH, patients had clinically and statistically significant improvements in VAS and ODI scores in all groups, as an objective measure of the success of treatment. More importantly, there were no differences among treatment groups indicating the validity of surgery for LDH when performed appropriately with these three different techniques. SF36 scores also improved following surgery, but were consistently lower at follow-up than those of the reference population matched by age, for both physical and mental health [24], indicating the impact of low back degenerative problems on the quality of life of the adult population. What differed substantially was the rate and type of complications that were more serious and common with MED, despite the long training curve of the surgeons involved in the study [2]. The Cochrane review came to similar conclusions by looking at 39 trials [6]; microdiscectomy gives broadly comparable results to open discectomy, but evidence on other minimally invasive techniques was unclear (with the exception of chemonucleolysis using chymopapain, which was no longer widely available at the time of the review).

Features of the study

For this randomised trial, sample size calculations were carried out [7] in order to ensure that clinically relevant changes would be detected. The number of cases per arm in our study is the result of statistical power analysis based on a retrospective internal pilot study. Our numbers are compared with those reported by other authors in the treatment of LDH with MED (Table 4). Although we were not allowed to blind the patients to the treatment groups, we tried to blind them from any expectation bias by presenting the three treatments as alternatives of equal validity [12], bearing in mind the high expectation of patients on the issue of minimally invasive surgery confirmed by the

Table 4 Synopsis of literature on lumbar MED, MD and OD

Reference	Year	Number of cases	Mean operative time (min)	Dural tear	Root injury	Wound infection	Recurrent LDH	Hospital stay (h)
[2] (MED)	2000	68	60	5%	0%	0.7%	2.6%	7.7
[14] (MED)	2003	30	109	NR	NR	NR	3%	NR
[17] (MED)	2002	41	110	4.4%	0%	0%	0%	16
[11] (MD vs. OD)	2006	62 (MD)	NR	NR	NR	1%	NR	36
		57 (OD)						
[20] (MED vs. OD)	2007	20 (MED)	>in MED	NR	NR	NR	NR	<in MED
		20 (OD)						
[21] (MED vs. MD)	2005	14 (MED)	NR	0.7% (MED)	NR	NR	NR	NR
		14 (MD)						
Present study (MED vs. MD vs. OD)	2009	70 (MED)	56 (MED)	8.7% (MED)	3% (MED)	0 (MED)	11.4% (MED)	54 (MED)
		72 (MD)	43 (MD)	2.7% (MD)	0 (MD)	5.5% (MD)	4.2% (MD)	49 (MD)
		70 (OD)	36 (OD)	3% (OD)	0 (OD)	4.2% (OD)	3% (OD)	49 (OD)
		212 (cohort)	45 (cohort)	12% (cohort)	2% (cohort)	3.1% (cohort)	6% (cohort)	51 (cohort)

NR not reported

proportion of those who preoperatively would have enjoyed being allocated to group 1. The dropout of 9% of enrolled patients had different reasons. Those patients in particular who were unhappy with the results of treatment and refused to participate further might have shed some light on the limitations carried by the different techniques. In the preliminary series presented by Foley and Smith [17] on MED, these surgeons reported 100% of good to excellent results according to the modified Mac Nab criteria. In the follow-up series presented by Perez Cruet and Foley [17] the proportion of cases having good to excellent results fell to 94%. The outcome was fair in 3% of the cases and poor in the remaining 3% due to recurrent disc herniations, which were treated with a repeat MED. In the series presented by Brayda-Bruno on MED [2], there were 94% good to excellent results. Four patients (6%) had unsatisfactory results at follow-up, due to persistent radicular pain in three and back pain in one compensatory patient. Katayama et al. [11] and Righesso et al. [20] in two prospective series compared MD to OD and MED to OD, respectively, again purporting evidence of no significant differences in outcomes at follow-up between techniques (Table 4).

The length of hospital stay for lumbar discectomy varies widely. Mean hospital stay in our series was 50 h overall. Hospital stays longer than 48 h were typical of patients with dural tears and did not reflect the type of surgery performed in the different groups. Given the higher incidence of dural tears in the MED group, these patients had longer hospital stays than patients in the other two groups. In various reports the length of postoperative stay ranged from 24 h to up to 3.7 days [3, 6, 11, 18, 20] (Table 4).

Technical considerations

During surgery, excellent illumination and magnification could be achieved by both MED and MD, but the main advantage of the operative microscope or surgical loops is their ability to maintain three-dimensional vision (stereopsis) while endoscopic surgery only allows for a bi-dimensional vision [2, 14, 17, 18, 20, 21]. The poor perception of depth with MED possibly resulted in a higher incidence of dural tears compared to both MD and OD [14, 20], and the restricting confines of the tubular retractor limited the ability of the surgeon to orientate the decompression instruments [2, 14, 20, 21]. Some authors have reported that this problem gradually fades away as the surgeon becomes more familiar with the video display of MED [2, 14, 21]; this was not our case. With microdiscectomy, the optics and light source are above the surgical field, requiring a larger incision and modified instruments to keep surgical tools and hands from obscuring the field of view [11, 18]. In the case of open discectomy the pitfall is that the operating surgeon's head can impinge into the light beam and that the assisting surgeon is often unable to achieve a satisfactory view of the operating field [11, 18, 20]. Different studies on MED revealed gradual reduction in the operative time with case proficiency. Perez-Cruet et al. [17] reported a mean operative time of 110 min in the first 30 cases, which was reduced to 75 min in the last 30 cases. In our experience the operative time in the MED group was 56 min in the lower range of the literature probably as a result of a long experience with the technique at the start of the study (Table 4).

Complications: types and rates

Dural tears, root injuries and recurrent herniations were all more prevalent in our study (group 1) than in previous retrospective ones [2, 14, 18] (Table 3). This finding is difficult to speculate on when one considers the long experience with MED of the surgeons involved in this study. One might conclude that the finding confirms the impression that retrospective studies are inevitably flawed with bias. The poor perception of depth with endoscopic surgery is possibly linked to a higher incidence of iatrogenic dural and root injuries compared to both MD and OD [14, 20], while the restricted field of work by the tubular retractor might justify a lower chance of identifying and removing free fragments within the disc space, ultimately leading to a higher incidence of LDH recurrences. On the other hand, minimal soft tissue trauma [2, 14, 17] is probably the reason why no wound infections were observed in the group of patients treated with MED, while the single case of spondilodiscitis in the same group may have possibly been favoured by an early reoperation performed for a recurrence of LDH. It was also noteworthy to observe no cases of pseudomeningocele in patients who suffered an iatrogenic dural tear in the MED group. We speculate that paraspinal muscle preservation and closure after the removal of the tubular retractor might favour the sealing of the dural tissue treated with fibrin glue. This information has the effect of making open conversions for dural repairs unnecessary when tears are produced during lumbar MEDs, and fibrin glue seals the tear in a satisfactory way intraoperatively.

Costs

The cost of discectomy for LDH has rarely been the object of research, despite its need [6]. In our study, MED was significantly more expensive than MD (intermediate) and OD (lowest cost per case) both as a single and as a repeat procedure when the cost of recurrences was taken into account. Nevertheless, overall costs compare well with published direct surgical costs for "disc surgery" in LDH averaging 4,685 US Dollars (2,900 Euros at the time of our study) [8].

In summary, MED, MD and OD show similar clinical outcomes when randomly applied to the treatment of LDH, but severe complications (dural and root injuries, recurrences) are significantly more frequent and surgical costs are higher with MED. As a consequence, we cannot recommend MED as routine practice for the treatment of LDH.

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