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Microendoscopic lumbar discectomy versus open surgery: an intraoperative EMG study

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Abstract This study investigated electromyographic (EMG) activity as a marker of nerve root irritation during two different surgical procedures for lumbar disc herniation. Mechanically elicited EMG activity was recorded during the dynamic stages of surgery in muscle groups innervated by lumbar nerve roots. Confirmation of surgical activity was correlated with the activity of the electromyogram. Fifteen patients with lumbar disc herniations were treated via an endoscopic medial approach, and 15 patients via the open microscopical surgical technique. Results indicated that the endoscopic technique

was superior to the open surgical technique and produced less irritation of the nerve root. Significantly less mechanically elicited activity was recorded during both the approach and the root mobilization. The study showed that microendoscopic discectomy allows a smaller incision and less tissue trauma with comparable visualization of the nerve structures than does open surgery.

Keywords Microendoscopic discectomy · Intraoperative EMG · Lumbar disc herniation

Introduction

Progressively less invasive procedures for lumbar disc herniations have been introduced since the use of chymopapain was described by Smith in 1964 [30]. In 1975, Hijikata [13] devised instrumentation for the percutaneous removal of the herniated disc material. From the late 1980s, laser vaporization was evaluated, but its use remained confined to intradiscal work [4, 12, 18]. Kambin and co-workers [16, 17] developed a set of instrumentation for percutaneous treatment of lumbar disc herniations, and reported an 87% success rate. Savitz [27] then modified this technique, combining it with the use of a laser. Schreiber and Suezawa used a contralateral approach, and inserted a fiberoptic discoscope for visualization [29]. Lateral percutaneous techniques, performed with difficult access to the L5-S1 interspace, have been described in a number of reports [11, 21, 28]. Onik and

colleagues [25] designed an automated percutaneous discectomy system with a suction-cutter, and a wide variety of other percutaneous discectomy techniques have been described [6, 7, 15, 19, 22, 24]. In order to address not only contained, but also free-fragment disc herniation, instruments were developed for the classical medial approach [5, 9]. Foley and Smith [9] designed the microendoscopic discectomy system (MED) in 1997. The objective of MED was the same as that of conventional open surgery: to decompress the nerve root. This was accomplished by applying open surgical techniques and tools through a tubular retractor under endoscopic visualization.

The purpose of this study was to compare endoscopic lumbar discectomy and open microscopic surgery regarding mechanically elicited electromyographic (EMG) activity as a measure of nerve root irritation.

Materials and methods

Subjects

Thirty patients undergoing a first-time lumbar discectomy for radiculopathy were studied with intraoperative EMG. Inclusion criteria were recurrent episodes of radiculopathy due to contained or non-contained disc herniation, confirmed by computed tomography (CT) or magnetic resonance (MR) imaging, and failure of adequate conservative treatment for at least 3 weeks. Exclusion criteria were: lumbar stenosis with narrowing of the spinal canal, thickening of the laminae and articular facets, calcifications, and migrating fragments extending further than half of the vertebral body. All patients were randomized by date of admission (either odd or even). Fifteen patients were treated endoscopically, 15 patients underwent open surgery. There were eight male patients and seven female (mean age 37 years, range 16–57 years) in the endoscopic group, and nine male and six female patients in the open surgical group (mean age 42 years, range 23–76 years). In each group, the level L4/5 was approached in seven cases and L5/S1 in eight cases. The mean preoperative duration of symptoms was 28 weeks (range 3–160 weeks) and did not differ between the two groups.

Anesthesia

In the majority of patients, anesthesia was induced with etomidate 16–26 mg, fentanyl 0.15–0.2 mg and rocuronium 50–80 mg. Anesthesia was maintained with alfentanil 25–100 µg/kg/h and 0.7–1.5% isoflurane endexpiratory. Train-of-four EMG recordings were made with a relaxograph monitor (Fisher+Paykel Electronics Ltd., Auckland, New Zealand) from the hypotenar, after ulnar nerve stimulation at the wrist. The patient had to demonstrate at least three twitches out of a train-of-four level of relaxation.

Electrophysiology

We monitored eight muscles simultaneously with eight EMG channels: three muscles (one proximal, one medial, one distal) on each side, corresponding to the nerve to be decompressed, and one muscle innervated by an adjacent root. In the case of an involved L5 root, bilateral recordings were obtained from the gluteus medius muscles, the anterior tibialis, the extensor hallucis longus, and the gastrocnemius muscles representing S1. In the case of an involved S1 root, the gluteus maximus, the gastrocnemius and the interosseous pedis I muscles, as well as the anterior tibialis for L5 were monitored. To record the EMG, pairs of subdermal needles were placed into the muscle, with the active one in the belly of the muscle. One reference electrode was placed 4 cm away, subdermally.

After the general anesthesia became effective, a baseline recording before skin incision was obtained and examined for 5 min for the presence of presurgery firing. The presence or absence of baseline firing was taken as a criterion for preoperative nerve root irritation. Intramuscular needles were used to obtain spontaneous intraoperative EMG in the free-running mode, using an Inomed machine (EWACS IOM System, Inomed Co., Teningen, Germany). The settings included a sweep time of 50 ms/div, with the high-cut filter set at 8000 Hz and the low-cut filter at 20 Hz. Sensitivity was 0.5 mV/div.

The degree of nerve root irritation was measured using our own six-grade scale. Grade 1 signifies no abnormal firing; grade 2, a duration of firing of less than 0.5 s associated with surgical manipulation; grade 3, the same duration of firing, but without manipulation; grade 4 a duration of firing of between 0.5 and 1 s associated with manipulation; grade 5, the same duration, but with-

out manipulation; and grade 6 signifies any firing lasting longer than 1 s.

The surgical procedure comprised several steps, which were announced by the surgeon and correlated to the EMG activity.

Endoscopic surgical technique

The instruments provided by Sofamor Danek represent standard neurosurgical tools that had been modified for use with the endoscope. The endoscope is introduced via a sequence of “dilators” that culminate in a 16- or 18-mm tubular retractor. The endoscope has a 100-mm working length, a 25° angle of view, a 90° field of view and a depth of field that ranges from 5 to 50 mm.

The patient is positioned prone with the abdomen free, and the spine is flexed, as in standard open microscopic surgery. The entry point starts 1.5–2 cm off the midline at the level of the appropriate disc space. A vertical incision of 18 or 20 mm is made at the puncture site. The guide wire is inserted under lateral fluoroscopy to the inferior edge of the superior lamina. The lamina is palpated with the dilator, thus ensuring proper location of the tip. Sequential dilators are inserted over each other under fluoroscopic control. The tubular retractor is then passed over the largest dilator and the dilators are removed. The retractor is connected to the flexible arm assembly, and the endoscope is inserted.

Soft tissue overlying the lamina and interlaminar space is removed with a pituitary rongeur. The laminar edge is identified and an appropriate laminotomy can be performed using a Kerrison punch (Fig. 1a). The yellow ligament is opened with a curved curette or a penfield, and resected with a Kerrison punch in a standard fashion. After flavectomy, the dura and transversing nerve root are identified (Fig. 1b). Medial retraction can be achieved with a penfield, a nerve root retractor or a suction retractor with an integrated sucker (Fig. 1c). If an annulotomy is necessary, it can be accomplished with the microknife while protecting the nerve root with the retractor. The herniated disc is then removed with the pituitary rongeur (Fig. 1d). After decompression, the tubular retractor is removed. The fascia, subcutaneous tissue and skin are reapproximated with one or two sutures.

Open microsurgical technique

A skin incision, varying from 3 to 6 cm, is performed. A 6-cm skin incision may become necessary in obese patients, with a body weight over 110 kg. The incision is carried down through subcutaneous tissue and the lumbodorsal fascia. The paravertebral muscles are swept laterally from the lamina in a subperiosteal plane, using the lamina as a landmark. The dissection is carried as far as the medial aspect of the facet joint. A Williams self-retaining retractor is placed, and a confirming localizing radiograph is taken. A flavectomy and partial hemilaminectomy without injuring the articular facets are performed under microscopic visualization. The thecal sac and nerve root are identified and the nerve root is mobilized. Epidural fat tissue and veins are dissected from the dorsal and lateral surface of the root, and bleeding veins are cauterized. A root retractor is used for medial retraction of the nerve root. Free fragments, if evident, are removed with a pituitary rongeur. The herniated disc is incised with a microknife and the herniated disc material and loose cartilage from within the disc are removed. A foraminotomy is accomplished to decompress the nerve root. The retractor is removed and wound closure is performed.

The main differences between the two techniques are in the approach, with the smaller skin incision being the same in obese patients, and with the muscle dilation instead of dissection, and with less bone removal in a narrow tubular retractor with the endoscopic technique. In practice, the approach into the spinal canal is a bit more lateral using the endoscope, coming from 1.5 to 2 cm paramedian, with the endoscope inserted obliquely. Thus, the

Fig. 1a–d Endoscopic surgical technique. **a** A hemilaminotomy is performed with a Kerrison punch. **b** After flavectomy, the dura becomes visible. **c** The nerve root is retracted medially, showing the disc herniation. **d** After annulotomy the herniated disc is removed

Fig. 2 Comparison of mean values of spontaneous electromyographic (EMG) scores during surgery

working channel is at an angle of 20° to 50° to the surface. The root mobilization with medial displacement can not be as great in a 16- or 18-mm channel, not exceeding 3 mm, in contrast to mobilizations of up to 6 mm in the open surgical technique. Furthermore, the intermittent use of the combined suction retractor instead of the root retractor in the open surgical technique does not lead to permanent pressure on the nerve root.

Data analysis

The gradings above grade 1 of all firing muscles were noted for each successive surgical step, and summarized at the end for each patient. The steps were: baseline irritation, muscle dissection, flavectomy, root mobilization, root retraction, removal of herniated disc, removal of material in the disc space, bipolar coagulation, and firing at the end. All mean values of the endoscopic group were compared to the open surgical group (Fig. 2). After affirmation of normal test distribution with the Kolmogorov-Smirnov test, statistical evaluation of the results was carried out using *T*-tests to indicate differences between independent samples. Probability values lower than 0.05 indicated a significant difference.

Results

Two-hundred and forty muscles, representing 120 nerve roots, were monitored in 30 patients. Mechanically elicited EMG activity was recorded from 60 proximal muscles in the open surgical group and 36 in the endoscopic group, and from 38 and 24 medial muscles, and 9 and 2 distal muscles in the respective groups. Fourteen muscles at other than the disc herniation level in the open surgical group and 15 in the endoscopic group showed EMG activity during root manipulation. Seventy-six ipsilateral and 45 contralateral nerve root irritations were recorded in the open surgical group, and 60 ipsilateral and 17 contralateral events in the endoscopic group.

A short discharge was typically recorded when the nerve root was irritated very briefly (grade 2) (Fig. 3). Only very few of these events were not directly correlated to a surgical manipulation (grade 3). Longer continuous discharges were detected only up to grade 4 (Fig. 4).

Regarding the operative steps, a presurgical firing was found in only four patients of the endoscopic group and one patient of the open surgical group (Fig. 5).

In four of our cases, nerve root irritation (six times ipsilateral, two times contralateral) occurred during the subperiosteal dissection of the paraspinal muscles, whereas no firing was seen passing the dilators over the guide wire in the endoscopic group ($P < 0.05$). With the exception of one grade 3 activity in the open surgical group, all patterns were considered to have been mechanically elicited.

EMG recording during flavectomy did not reveal any statistically significant difference between the two groups (mean value 2.7 vs 3.6). However, there were 17 EMG events (12 ipsi-, 5 contralateral, three grade 4) in the endoscopic group and 27 events (16 ipsi-, 10 contralateral, one grade 4) in the open surgical group.

Root mobilization was more gentle with the endoscopic technique (mean value 1.7 vs 4.2, $P < 0.02$). Thirteen muscles fired in the endoscopic group (10 ipsi-, 3 contralateral) and 29 (19 ipsi-, 10 contralateral) in the open surgical group. Endoscopically, all events were short-lasting (grade 2), whereas in the other group two events were graded as grade 4 and one as grade 3.

In 13 muscles of our open surgical group, unilateral nerve root retraction caused nerve root irritation (eight ipsi-, five contralateral, two grade 4). In the endoscopic

Fig. 3 Mechanically elicited EMG activity of three L5 muscles and one S1 muscle during root retraction in a right-sided disc herniation at L4/5 in the open surgical group

Fig. 4 Mechanically elicited long-lasting bilateral EMG activity during root retraction in a left-sided disc herniation at L4/5 in the open surgical group

Fig.5 Spontaneous EMG activity at the beginning of the surgical procedure in a left-sided disc herniation at L4/5 in the endoscopic group, showing bilateral firing of the proximal L5 and medial S1 muscles

group, there were seven ipsilateral events. Mean values did not differ significantly (2.0 vs 0.9).

Removal of herniated disc material produced three events in the open surgical group, and seven short-lasting events in the endoscopic group (mean value 0.4 vs 0.8, n.s.). Removal of material within the disc space did not differ between the groups (24 events, mean values 3.5, two grades 4 vs one grade 4).

During bipolar coagulation, firing was recorded from 13 muscles in the open surgical group and 3 in the endoscopic group (mean values 1.7 vs 0.4, n.s.).

At the end, there was spontaneous activity in four muscles of the open surgical group (one grade 3) and no activity whatsoever in the endoscopic group (mean values 0.6 vs 0.0, n.s.).

The sum of all mean values of the different surgical steps varied significantly between the open surgical and the endoscopic group (17.8 vs 11.6, $P < 0.03$).

At discharge, all patients showed good relief of their preoperative radicular complaints. No new deficits were observed postoperatively for either group. There was only a tendency in the self-rating of intensity of pain (scale 1–10) to lower scores and less pain in the endoscopic group (n.s.).

Discussion

Intraoperative electromyographic techniques have been successfully employed in a variety of neurosurgical procedures [1, 2, 3, 10, 14, 20, 23, 26, 31]. Besides thoracolumbar scoliosis surgery [14], this modality has found an increasing acceptance in procedures in which pedicle screw placement might potentially cause neuronal injury [1, 2, 3, 20, 23, 26, 31]. Evoked EMG activity can be recorded with defects in the pedicle wall [3, 20]. Intraoperative monitoring of EMG has shown a correlation between the presence of neurotonic discharges in muscles from appropriate myotomes and lumbosacral nerve root

manipulation [2, 14, 26]. EMG is regarded as more sensitive than mixed-nerve and dermatomal sensory evoked potentials (SEPs) for detecting lumbosacral radiculopathy [14].

Beatty et al. [2] reported electrical discharges in 90% of their patients undergoing lumbar surgery for radiculopathy. In 18% of lumbar laminectomies, spontaneous firing was noted during baseline recording. The presence of presurgical firing was associated with clinical weakness in 64%. In 76% of the firings in Owen's group [26], the level of muscle activity correlated exactly with the surgeon's activity. EMG activity correlated with the confirmed segmental level of surgery in 98% of the nerve roots that demonstrated activity. In 17% of Fountas and co-workers' cases [10], excessive unilateral nerve root retraction caused contralateral nerve root irritation.

In our study, 45 of 121 events with mechanically elicited EMG activity in the open surgical group and 17 of 77 events in the endoscopic group were associated with contralateral nerve root irritation. Cessation of this maneuver caused termination of EMG evidence of irritation. Force transmission across the midline may have pushed the contralateral nerve root against osseous tissue, causing direct mechanical pressure as well as secondary ischemic changes referable to nerve root microcirculation. Eight events of the open surgical group demonstrated nerve root irritation during the subperiosteal dissection of the paraspinal muscles from the underlying laminae before the spinal canal was entered, suggesting that a particularly compromised nerve root is susceptible to even subtle transmitted force. There was a significant difference between the two groups. Nerve root irritation during the dissection of the paraspinal muscles occurred only in the open surgical group, whereas no firing was seen passing the dilators over the guide wire in the endoscopic group. Thus, the endoscopic approach seems to lead to less tissue trauma.

The extent of bone removal with exposure of the spinal canal is more excessive in the open surgical technique.

However, in our study, there was no significant difference in nerve root irritation between the groups at this point.

Twenty-nine events involved the ipsilateral adjacent nerve root at a higher level during removal of disc material from the far lateral side of the disc space, due to mechanical irritation of the descending higher nerve root.

Root mobilization caused less EMG activity in the endoscopic group. Working through a 16- or 18-mm channel may lead to less extensive movements with limited preparation to that working space, and therefore more gentle mobilization. In our opinion, the more lateral approach in combination with the limited working area and reduced medial displacement of the nerve root explain the lower grade of nerve root irritation in the endoscopic technique.

Only large muscle groups showed a high frequency of mechanically elicited activity. The muscle bellies of distal muscles such as *M. extensor hallucis* and *M. interosseus pedis I* are too small to detect extensive EMG activity. It remains unclear whether proximal muscles such as *M. gluteus maximus et medius* are more susceptible to showing indications of root irritation than are medial muscles such as *M. gastrocnemius* and *M. tibialis anterior*. In our study, mechanically elicited activity was detected in 96 proximal muscles, but only 62 medial muscles.

Despite the EMG differences between our two groups, it remains questionable as to whether the mechanical irritation induced by a surgical instrument will result in a clinically relevant postoperative radiculopathy. At discharge, there were no significant differences in clinical signs between our two groups and no new postoperative deficits. In the endoscopic group, only a tendency to lower scores of self-rated postoperative pain could be shown. So far, almost all studies addressing the question of the prognostic value of EMG have been conducted pre-

and postoperatively. Falck et al. [8] reported that the preoperative EMG finding had no prognostic significance in determining the outcome 5 years later. A normal EMG finding both at the 1-year and 5-year follow-ups, however, was related to good outcome. Muscles showing signs of old neuropathy, large motor unit potentials and reduced interference pattern were related to a poor outcome. Obi et al. [23] found that intraoperative mechanical irritation of the nerve root elicited nerve root discharge with no postoperative nerve root deficit. Balzer et al. [1] reported on two cases out of 44 with pedicle screw instrumentation in which changes in somatosensory evoked potentials (SSEPs) and spontaneous EMG activity were noted and were correlated with postoperative patient complaints. Beatty et al. [2] described a 20–23% false-negative rate, in which no firing was obtained with nerve root retraction. That is consistent with our observation that sometimes even severe manipulations at the nerve root do not necessarily lead to recordable discharges, and limits the method.

Conclusions

The microendoscopic system offers the benefits of a smaller incision than using microdiscectomy, and limited tissue trauma via sequential dilation. It causes less mechanically elicited EMG activity as a marker for nerve root irritation. The question of whether minimization of intraoperative nerve root irritation may minimize postoperative pain and long-term distress has to be clarified with long-term follow-ups. Additional outcome analysis seems to be called for.

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