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Dry Needling (Intramuscular Stimulation) in Myofascial Pain Related to Lumbosacral Radiculopathy

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Summary: "Dry" needling or non-electrical and non-chemical intramuscular stimulation (IMS) has been found use in the treatment of myofascial pain. To understand the effects of IMS on pain symptoms, patients with trau induced low back pain (LBP) and radicular symptoms had electromyography (EMG) performed at painful myofas bands from bilateraL L2 to S1 myotomes with physical examination before and after the EMG. Eighty patients rep to follow-up questionnaires obtained 2 weeks after the test. Group 1 (68.8%) had pain relief, and Group 2 (31. had no pain relief after the EMG. In the control group with similar symptoms where EMGs were performed with prior palpation, pain relief (CG-PR) occurred in 18 of 25 patients (72%). Root level involvements were diagnosed the presence of increased percentage (> 30%) of normal duration, normal amplitude polyphasic motor unit act potentials (MUAPs) in a myotomal pattern. Bilateral findings were noted in all patient groups regardless of sympto with common involvement of L4, L5, S1 nerve roots. Groups 1 and 2 were similar in age and EMG findings, Group 1 patients had less pain on palpation of different myotomes, with shorter duration of symptoms, and improvement in physical examination after the EMG. The CG-PR patients when compared to Group 1 were older had similar EMG findings, duration of pain relief (average 8 days), and physical improvement after the EMG, but CG-PR had significantly fewer patients with immediate pain relief and >= 50% pain relief, and no patients with 75% pain relief. Painful points on myofascial bands were found to be motor end-plate zones and pain relief is to adequate desensitization of these areas from evoking twitch responses at EMG or clinical level. This study help in understanding the use of IMS for the management of patients with myofascial pain due to neuropathic caus and 5 case reports are offered to demonstrate the effectiveness of IMS. **(Eur. j. phys. med. rehabil. 1995;5:106-**

Introduction

"Dry" needling of the tender motor points had been reported by *Gunn* to be useful in the treatment of low back pain (LBP) of neuropathic origin related to spondylotic conditions of the spine (23, 24). The pain relief with dry needling was also noted by others who suggested that the intensity of the painful stimulus from mechanical irritation of the needle seemed to be the crucial factor for producing the needle effect and pain relief (18, 39). In EMG, a pin electrode is inserted into muscles for detection of electromyographic signals. During the EMG, the pin is moved in all directions for examination of the electrical activity of the muscle during rest, minimal and maximal contraction. These pin movements are often pain provoking, therefore the author expects the EMG examination to have an effect on the patient's pain symptoms.

The questions that the author wished to answer are:

1) Could the "dry" needling from a single EMG examination effect a patient's painful symptoms, and if so will the effect be pain relieving or pain provoking?

2) If a change in pain pattern is obtained, are there clinical or electromyographic predictors that differentiate patients who will achieve pain relief from those who will not achieve pain relief after a single EMG examination?

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3) Could the information from this study explain why p ful symptoms are affected by the insertion of a pin muscles?

4) Knowing the characteristics of the patients and the nomenon, if any, observed during needling of muscles this method of IMS be used as a major modality in the agement of patients with chronic pain of neuropathi gin?

Subjects and methods

Patients referred to the author's electrodiagnostic la tory for complaints of LBP with associated lower extre pain were examined by the author for electrodiagn procedures. The period of study was between October and March 1993. The electrodiagnostic studies were th nerve conduction studies including F waves of the bila perineal and tibial nerves, and sensory studies of the nerves. The bilateral tibial nerve H-reflexes and F-resp es were also recorded from the soleus muscle. The was performed bilaterally to include the following mus sartorius (L2), adductor longus (L3), vastus medialis lateralis (L4), tibialis anterior (L5), extensor digit longus (L5), extensor hallucis longus (L5), tensor f latae (L5), gluteus medius (L5), flexor digitorum lo (S1), soleus (S1), biceps femoris, long head (S1), glu maximus (S1) and the paraspinal muscles at L2, L3, L and S1 levels as well as the T12 levels at about one hal from the spinous process.

The nerve conduction studies and EMG were perform described in *Chu-Andrews* and *Johnson* (11) and the e ination was performed bilaterally. The EMG was perfo in the first group of consecutive patients without palpation prior to the EMG. In the second group of consecutive patients, the pin penetration was preceded by palpation of the muscle for presence of a myofascial band with the pin insertion site at a painful point along this band, when felt. When the location of the muscle precluded deep palpation of the myofascial bands such as in the extensor hallucis longus and the gluteus maximus muscles, standard points were chosen for pin penetration (11). The examination of the paraspinal muscles was done at one half inch away from the spinous process. Each of the muscles was penetrated at 2 skin insertion sites and the muscle was examined in different directions and at different depths for electrical activity at rest, minimal and maximal contraction. The MUAPs were studied by the method of triggering and delaying the MUAP activity at a sweep speed of 5 ms/division (57). 20 MUAPs were semi-quantitatively analyzed at each skin insertion site by examination at different quadrants of the muscle, with the recording made from 20 different positions within the muscle separated by at least 3 mm (7). Morphology of the MUAPs for amplitude, duration, number of phases and percentage of polyphasia was determined. The TD 20 EMG machine (TECA Corporation, White Plains, New York) and disposable TECA monopolar MF 37 needles were used for the examinations.

A diagnosis of recent onset and ongoing radiculopathy was made primarily on the presence of increase in the percentage of polyphasic potentials (> 30%) with normal duration (< 15 ms) and normal amplitude (< 4 mV). Presence of chronic partial radiculopathy was made on the presence of increase in the percentage (> 10%) of long duration triphasic potentials (> 20 ms) with large amplitude (> 4 mV) (11). The diagnosis was made only when the potentials were present in a myotomal pattern including the paraspinal muscles in the absence of peripheral neuropathy. All patients having evidence by nerve conduction study of peripheral neuropathy were excluded from this study. The degree of severity of recent onset involvement was classified as grade 1 when the percentage of increase in normal duration, normal amplitude polyphasic MUAPs >= 30% and <= 50%, grade 2 when the increase in polyphasia > 50% and <= 75%, grade 3 when the increase in polyphasia > 75%, and grade 4 = any of the above with presence of spontaneous activity.

Prior to the EMG study, the patients underwent a detailed physical examination including goniometric measurements of range of motion (R.O.M.) of the ability of the lumbosacral spine to

1) flex and
2) extend at the hip at the level of the greater trochanter.
3) Lateral flexion of the spine to each side was measured by the distance (cm) between the tip of the pulp of the middle finger and the lateral end of the knee crease.
4) Ability of the patients to perform a straight leg raising test in the supine position was also measured in degrees bilaterally. Thus 4 different types of R.O.M. were measured.

The 5 strength tests were performed in the following fashion.

1) The extensor hallucis longus muscle strength was graded according to the Medical Research Council scales (however, 0.5 scales were added when the muscle withstood mild resistance between the full scales).
2) Dorsiflexion of the ankle (patient's ability to stand on the heel with weight bearing only on the lower limb that was being examined; the one best distance [cm] between the floor and the plantar surface of the first metatarsophalangeal joint was measured).
3) Plantar flexion of the ankle (patient's ability to stand on the toes with weight bearing only on the lower limb that was being examined: the one best distance [cm] between the floor and the plantar surface of the heel was measured). In both testings for dorsiflexion and plantar flexion, the patient was instructed to use the examination table for balance purposes only, with hands on the table, but not to push down on the table and weight bear on the arms in order to improve the ability to do the test. The measurements were done only when the patient was vertical alongside the bed.
4) The ability of the patient to perform the Trendelenburg testing with weight bearing on alternate lower limbs and the testing was noted to be positive when the patient listed to the same side in order not to drop the contralateral non-supported pelvis or when there was an obvious drop in the non-supported contralateral pelvis.
5) Ability of the patient to squat without or with support using hands on the examination table.

The paraspinal muscles were also palpated for the presence of spasm, and the degree of tenderness felt by the patient when key muscles were pressed into, using the blunt end of a "Paper Mate" ball point pen. Pressure is applied sufficiently firmly to compress the muscle between the tip of the blunt end of the pen and the underlying bone. Similarly, the degree of tenderness at the motor points of the representative key muscles of L2-S1 myotomes was noted. The patient was instructed to grade the pain felt when pressure was applied at the myofascial bands. *Gunn* and *Milbrandt* (21) described 4 major grades of quantifying the tenderness at the motor points.

Grade 0: No tenderness whatsoever is elicited by firm pressure.
Grade 1: Patient is aware of some tenderness as pressure is applied but it is not unpleasant.
Grade 2: Tenderness is moderate and unpleasant.
Grade 3: Tenderness is acute, so that the patient is often surprised and reacts vigorously.

The following key muscles of each root innervated by the L2-S1 myotomes were examined, namely: sartorius (L2), adductor longus (L3), vastus medialis (L4), gluteus medius (L5), tibialis anterior (L5), gluteus maximus (S1) and medial head of gastrocnemius (S1). In the paraspinal muscles, only the worst grading of tenderness was recorded. The degree of tenderness graded on palpating the motor points of each muscle was then added, with the maximum sum attainable being 24.

Immediately after the EMG, the patient was re-examined again for all the same physical parameters. The spine R.O.M. for extension was considered significantly changed when the change was >= 10 degrees. The ability to do the straight leg raising testing was considered significantly changed when the change noted was >= 15 degrees. The ability to anteriorly or laterally flex the spine as well as the ability to dorsiflex and plantarflex the ankle was noted to have significant changes only when the change in measurement was >= 2.0 and 2.5 cm, respectively. These numbers were chosen since repeated prior measurements of the same parameters on normal subjects for the reproducibility of measurements determined that the measurements are easily reproducible within 1 to 2 cm or within 10 degrees. Strength was noted to be improved in the extensor hallucis longus when the grading improved by 0.5 grade on a scale of 0 to 5. Changes in Trendelenburg testing were noted when there is obvious absence or worsening of drop in the non-supported contralateral pelvis when standing only on one leg. A change in the ability to squat was noted when there was no need or less need for external support in accomplishing the squat or less ability to squat after the EMG.

Different combinations of changes in R.O.M. and/or strength after the EMG were noted and classified into 5 major categories. Category 0 (0 to 6 grades) included those patients with no changes in the 4 different types of R.O.M. examined but with 0 to 5 changes in strength. Examples of the grading system are as follow:

Grade 1: No significant changes in any R.O.M. or strength testing.

Grade 2: No improvement in R.O.M. and 1 improvement in strength testing.

Grade 3: No improvement in R.O.M. and 2 improvements in strength testing.

Grade 4: No improvement in R.O.M. and 3 improvements in strength testing.

Grade 5: No improvement in R.O.M. and 4 improvements in strength testing.

Grade 6: No improvement in R.O.M. and 5 improveme in strength testing.

Category 1 includes (Grades 7 to 12), Category 2 (Grades to 18), Category 3 (Grades 19 to 24) and Category 4 (Gra 25 to 30). The Category number denotes the numbe R.O.M. changes and the grades denote the number of ferent changes in strength improvement.

Changes in the total motor point tenderness after the E was noted when there was a total change in tendernes >= +3/−3 points after the EMG from that obtained be the EMG. This was also done for the testing of the mo point tenderness of the control muscle which was the dial gastrocnemius muscle. Control motor point chan were taken as significant when the change was >= +2 points before and after the EMG.

The patient was also given a questionnaire to be retur to the examiner in 2 weeks. The questionnaire addres the following points:

1) Whether relief/worsening of the pain was obtained a the EMG examination.

2) How many days after the EMG did the pain relief/w ening occur?

3) The average pain level in the 2 weeks after the EMG t marked on an increasing numeric pain scale of 0 to 1 compared to one filled in before the EMG examination.

4) How many days did pain relief/worsening last?

Results

80 patients returned the questionnaires, which was proximately 20% of patients with complaints of LBP by the author for electrodiagnosis in the time perio tween October 1991 and March 1993. The following ta will not show the mean values or the statistical analys the control patients with no relief (CG-NR), due to the s number of patients in this group.

Table 1. General Characteristics of patient studied.

Patient profile	Group 1	Group 2	CG-PR	CG-NR
Auto accidents	34 (d = 24, p = 10)	8 (d = 6, p = 2)	14 (d = 13, p = 1)	3 (p = 3)
Work accidents	17	14	3	3
Other causes	4	3	1	1
Total studied	**55**	**25**	**18**	**7**
Males	33	11	9	2
Females	22	14	9	5
Unilateral symptoms	26	14	5	2
Bilateral symptoms	29	11	13	5

Table 2. Specific characteristics of patients studied.

Patient profile	Group 1	Group 2	CG-PR
Age (years)	37.1 ± 10.7 (#)	40.7 ± 14.3	44.7 ± 13.9
Symptom duration (months)	14.0 ± 16.8	25.5 ± 28.2 (#)	11.9 ± 19.1
Abn. roots on sym. side (no)	3.2 ± 1.1	3.4 ± 1.3	2.7 ± 0.9
Abn. roots on asym. side (no)	2.8 ± 1.1	3.0 ± 1.4	2.5 ± 1.1
Degree of abn. of most involved root (sym. side no)	1.6 ± 0.9	1.8 ± 1.3	1.4 ± 0.9
Degree of abn. of most involved root (asym. side no)	1.2 ± 0.6	1.1 ± 0.6	1.3 ± 0.8
F & H diff. on sym. side (ms)	4.4 ± 1.9	4.4 ± 1.5	4.2 ± 1.7
F & H diff. on asym. side (ms)	3.9 ± 2.1	4.4 ± 1.7	4.2 ± 1.8
Total motor point tenderness on sym. side (no)	12.4 ± 6.0	15.4 ± 5.0 (#)	12.6 ± 5.4
Total motor point tenderness on asym. side (no)	10.3 ± 5.7	13.5 ± 6.0 (#)	10.4 ± 5.9
Average pain relief (days)	8.0 ± 7.4	–	8.4 ± 7.6
Increased pain after EMG (days)	1.4 ± 2.2	7.4 ± 5.5 (##)	3.2 ± 3.2
Phys. improve level (no)	9.0 ± 5.7	4.6 ± 3.9	8.1 ± 6.5
Amount of pain relief (%)	49.5 ± 25.2 (#)	–	34.9 ± 19.1
Immediate pain relief (% of patients)	52.7 (**)	27.8	35.7

Abbreviations: d = driver, p = passenger, no = number, ms = milliseconds, abn = abnormal, sym = symptomatic, asym = asympto phys = physical, diff = difference

(#) = p < 0.05 (t test); (##) = p < 0.01 (t test); (**) = p < 0.01 (chi square)

Table 3. EMG findings in patients studied.

EMG abnormalities profile **(symptomatic limb)**	Group 1	Group 2	CG-PR	CG-NR
one root involved (%)	1.8	8.0	0	0
(L5 or S1)	(1/55)	(2/25)	(0/18)	(0/7)
Two roots involved (%)	30.9	36.0	61.1	42.9
(L5, S1)	(17/55)	(9/25)	(11/18)	(3/7)
>= 3 roots involved (%)	67.3	64.0	38.9 (*)	57.1
(L4, L5, S1; L3, L4, L5, S1 or L2, L3, L4, L5, S1)	(37/55)	(16/25)	(7/18)	(4/7)
(Asymptomatic limb)				
One root involved (%)	1.8	0	11.1	0
(L5 or S1)	(1/55)	(0/25)	(2/18)	(0/7)
Two roots involved (%)	50.9	36.0	55.6	71.4
(L5, S1)	(28/55)	(9/25)	(10/18)	(5/7)
>= 3 roots involved (%)	47.3	64.0 (*)	33.3	28.6
(L4, L5, S1; L3, L4, L5, S1 or L2, L3, L4, L5, S1)	(26/55)	(16/25)	(6/18)	(2/7)

Note: (*) = $p < 0.05$ with chi square test; % = percentage of patients

Physical examination.

Improvement: Table 4 shows only those parameters where more than one third (33.3%) of the patients showed an improvement as defined in the text.

Discussion

Relating to IMS and clinical findings

Previous studies have confirmed the therapeutic effects of "dry" needling (IMS) on myofascial pain (18, 21, 24, 30, 39). These studies, however, have not established guidelines about the use of this procedure in the long term management of myofascial pain due to neuropathic causes. By performing the present study, it is the goal of this author to gain a better understanding of the "dry" needling effects, in order to utilize the IMS procedure more effectively, and even as the sole or major physical modality in the management of myofascial pain of neuropathic origin.

Although only 20% of the questionnaires were returned, the author was able to determine that the IMS effect associated with an EMG can affect a patient's original pain symptoms. The pain symptoms may increase or decrease for about of a week. Several helpful clinical and electromyographic predictors were noted that can differentiate relatively, who will and who will not achieve pain relief with a single episode of IMS such as that associated with an EMG. The characteristics of patients who had pain relief after EMG in the painful areas of myofascial bands (Group 1, Table 2) tended to be significantly younger, had shorter duration of symptoms, less tender muscles on palpation of motor points, and showed a higher level of improvement in physical function immediately after the EMG. There was also a pattern of immediate relief of pain after the EMG, and even for those patients who had an increase in pain after the EMG, the duration of increase in pain was significantly shorter than in the control group with pain relief (CG-PR). Compared to the CG-PR, Group 1 had a significantly higher number of patients who had >= 50% pain relief. Group 1 also showed a small percentage of patients (14%) who had >= 75% of pain relief, whereas no patients in CG-PR obtained >= 75% pain relief. Group 1 patients also showed a correlation between the percentage of pain relief with the number of days of pain relief obtained by the patients, and such a correlation was not noted for CG-PR patients. The more significant intensity of the pain relief in Group 1 pa-

Table 4. Improvements noted in physical examinations after EMG.

Range of motion improvement	Group 1 (%)	Group 2 (%)	CG-PR (%)
Anterior flexion	52.7 (29/55)	28.0 (*) (7/25)	44.4 (8/18)
Lateral flexion (Sym. side)	56.0 (17/55)	12.0 (**) (3/25)	35.8 (6/18)
Strength improvement Trendelenburg test (Sym. side)	40.0 (**) (22/55)	20.0 (5/25)	0 (0/18)
Motor point tenderness improvement (total score)			
Sym. side	36.4 (20/55)	8.0 (**) (2/25)	38.9 (7/18)
Asym. side	35.5% (11/55)	16.0 (**) (4/25)	38.9 (7/18)

Note: Significance is indicated by (*) = $p < 0.05$; (**) = $p < 0.01$ (chi square)

A significant correlation was found between the percentage of pain relief and the number of days of pain relief. No correlation was found between the percentage of pain relief and age, number and degree of nerve root involvement and the level of physical improvement.

Table 5. Available MRI scan findings in patients studied.

	Group 1	Group 2	CG-PR	CG-NR
MRI (available)	30/55 (54.5%)	10/25 (40%)	5/18 (27.8)	5/7 (71.4%)
Normal	7/30 (23.3%)	1/10 (10%)	1/5 (20%)	1/5 (20%)
HNP	5/30 (16.7)	3/10 (30%)	1/5 (20%)	3/5 (60%)
DJD	16/30 (53.3%)	6/10 (60%)	1/5 (20%)	1/5 (20%)
Stenosis	2/30 (6.7%)	0/10 (0%)	2/5 (40%)	0/5 (0%)

Note: HNP = Herniated nucleus pulposus; DJD = Degenerative joint disease, includes also those with bulging discs.

tients underscored the importance of needling the tender points along the myofascial bands as opposed to needling random areas in the muscles as in CG-PR patients. The CG-PR patients who also had myofascial pain syndrome due to neuropathic causes as identified by EMG and presence of tender motor points had pain relief due to nonintentional needling of myofascial bands, even though these bands were not previously identified by careful palpation. However, because the most painful point along the myofascial band, usually the motor end plate zone, had not been needled, the pain relief in the CG-PR patients was significantly less quantitatively than in Group 1.

The characteristics of patients who did not have pain relief after a single EMG examination at the painful area of the myofascial band (Group 2, Table 2) tended to be those with a higher total score for tenderness of motor points. They were also older than Group 1, and tended not to show an improvement in R.O.M. after the EMG, and generally performed more poorly in the physical examination testing after the EMG.

Gunn had shown that patients with pain symptoms due to radicular involvement had significant tenderness at the motor points (21). This is due to nociceptor sensitization, which accompanies tissue trauma and inflammation (21, 46). In this study also, Group 2 patients had a higher total score for tender motor points. These patients' poor response to one episode of needling may be related to more intensity of nerve pathology in the involved nerve root or roots, unilaterally or bilaterally, or due to more numbers of nerve roots that are involved unilaterally or bilaterally. This will lead to a higher number of involved muscles or more intensity of pain and/or spasm in the involved muscles. The muscles supplied by a greater number of involved nerve roots are thus not likely to be adequately relieved of pain with the 1 to 2 skin penetration sites for IMS such as that associated with a single EMG examination. These muscles will have more focal areas of muscle spasm, and more scattered and wide-spread presence of tender myofascial bands. In addition, the longer duration of symptoms in Group 2 indicates that the changes in the inherent properties of muscle elasticity due to chronic nerve root irritation may play a significant role in maintaining pain. In such situations, there is muscle shortening, not only due to spasm, but also due to stiffness and tightness related to fibrosis with resultant mechanical manifestations (26). However, the fact that more nerve roots are involved or more pathology was present in the involved root or roots in Group 2, was not significant in the author's study. It was however noted that a higher percentage of patients in Group 2 showed >= 3 roots involved on the asymptomatic limb as compared to Group 1 or CG-PR patients. The inability to document more numbers of root involvement or more significant degree of pathology in the involved nerve root or roots in Group 2 patients may be related to the small numbers of patients in this group. Inherent flaws may also be present in the author's method of semi-quantitative analysis of MUAPs. A more sensitive method of MUAP analysis or other techniques of studying the motor unit may be required to document these facts.

In Group 1 patients and CG-PR patients who had relief of pain after an EMG examination, the average level of physical functioning improved significantly immediately after the EMG. These patients were in Category 1 improvement indicating that there was an improvement in one R.O.M. measurement. The strength improved 1 or 2 levels respec- commonly improved was anterior flexion of the lumbos cral spine and the strength improvement commonly not was an improvement in Trendelenburg testing (Table 4). all patient groups in the study, an average of 80% of the p tients in Groups 1 and 2 and CG-PR belonged to <= Categ ry 3 for R.O.M. improvement, with 0 to 3 grades of streng improvement. The author is in agreement with Gunn (2 that pain is due to mechanical manifestations of shorten muscles, since the pain relief as noted by the author w dependent on the improvement of R.O.M. primarily, whi would then lead to a secondary increase in strength. Th was also illustrated in the case descriptions where t range of motion improvement was noted more clearly a quickly with subsequent improvement in strength. T strength improvement is related to pain reduction rath than to true increase in strength.

Assessment of improvement in motor point tenderness w not a reliable criteria for assessment of pain relief althou it was noted that significantly fewer patients in Group 2 c show an improvement in this parameter after the EM Since the examined areas were still painful from the ne dling, the author does not place much significance on po needling tenderness, or lack of tenderness at the mo points as an indication of the completeness or incomple ness of desensitization at that point.

The author was able to document that there were EMG a normalities in multiple bilateral root distributions in p tients with myofascial pain syndrome, regardless of t side of symptoms (Tables 1 to 3). Thus, to relieve pa symptoms, desensitization should include IMS to multip muscles in multiple myotomes.

Relating to IMS and EMG findings

When a spinal nerve root compromise occurs such as th caused by progressive compression, as from a herniated tervertebral disc, Wallerian degeneration of the large mo fibers will result in spontaneous activity such as posit sharp waves and fibrillations. The finding of spontaneo activity in a myotomal distribution is usually the princip sign used in electromyography to diagnose root level volvement. When an injury involving the nerve roots is d to tensile stretch/distortion injuries, the EMG examin tion at rest may not reveal spontaneous activity, since t involvement is less severe than that of progressive extrin nerve root compression such as from a herniated disc. W tensile stretch/distortion injuries, the denervation may partial and random, and can thus be readily re-innervat by neighboring healthy axons.

The majority of the patients in the study were those volved in motor vehicle accidents and work related injuri primarily those involved with lifting or twisting injuries (T ble 1). It has been shown by *Sunderland* that the spi nerve roots are the sites most vulnerable to trauma si they lack epineural and perineural tissue, the fibers are ranged in parallel nonplexiform bundles, and the collag fibers of the endoneural tissue are fewer and finer th elsewhere (58). Therefore, with trauma to the spine, in ries to multiple nerve roots can easily occur and are di nosable on EMG studies. Patients in this study were se for electrodiagnosis by the author many months after th original injury. Thus, even if the spontaneous activity h been present earlier due to the original injury, the spon neous potentials may not be detectable at the time of EMG examination since the denervated muscle fib

In vitro studies in amyotrophic lateral sclerosis have indicated the presence of muscle fibers in a state of innervation where the motor neuron is unable to maintain its full trophic influence on the muscle fiber membranes, causing formation of extra-junctional receptors. A frank denervation does not develop since some trophic influence is still present (61). This phenomenon may play a role in some of the cases where frank denervation was not noted and the polyphasic MUAPs were large in amplitude and long in duration, but this is unlikely to be the mechanism in the majority of the cases where normal duration, normal amplitude MUAPs were noted (Figs. 1 and 2).
Previous literature had shown that polyphasic MUAPs were useful in the diagnosis of radiculopathy (13, 32, 36, 38). However, the significance of these potentials in diagnosis of radiculopathy is still debated. Some have not regarded these polyphasic MUAPs as being useful in the diagnosis of radiculopathy (35, 62), especially when the duration and amplitude of these MUAPs are within normal limits. The author has commonly observed the presence of increased incidence of polyphasic MUAPs of normal duration and normal amplitude in multiple myotomal patterns bilaterally in the patients with chronic myofascial pain. These polyphasic MUAPs are very simplified in shape with only 5 to 6 phases or turns (Fig. 1) and are more noted in quantity in muscles supplied by the more involved roots. As re-innervation proceeds, these normal duration, normal amplitude MUAPs become more complex in shape (Fig. 2).
Polyphasic MUAPs are noted with abnormalities of the motor unit. Those polyphasic MUAPs that occur with re-innervation are due usually to collateral re-innervation from the most adjacent surviving motor unit. The polyphasic MUAPs in such situations are long in duration and complex in shape (2). This is due to an increase in the average number of muscle fibers per remaining motor unit (4, 52, 56). As the re-innervation matures, the conduction velocities in terminal nerve branches increase, resulting in relative decreases in polyphasia with increases in amplitude and duration, and eventually the MUAP may regain its triphasic shape. Re-innervation by regrowth of the original axon back to the muscle by axonal regeneration in partial nerve lesions is less common. This is not only due to the distance involved to the denervated muscle fibers which usually get re-innervated through collateral re-innervation, but also because axonal re-innervation is usually associated with complete nerve transection (3).
The pathophysiology of polyphasic MUAPs include:
1) loss of muscle fibers within the motor unit;
2) block in conduction in nerve branches in the terminal arborization;
3) failure of neuromuscular transmission;
4) degeneration of nerve terminals; and
5) synchronous, but not simultaneous firing, of 2 or more motor units (37). Factor (1), which involves loss of muscle fibers such as that noted with primary muscle diseases, may be considered as a possible cause of polyphasia, but the duration and amplitude tend to decrease in these situations (9). Factors (2 to 4) as mentioned by *Lambert* (37) as well as fiber diameter variation as mentioned by *Buchthal* (6, 9) can also be the cause of the normal duration, normal amplitude polyphasic MUAPs. Single fiber electromyography examination may be more useful than conventional EMG to determine whether the cause is neurogenic, myogenic or otherwise (55). Factor (5) may cause polyphasia due to ephatic transmission in the area of inflamed roots (12). It has also been noted that sick axon terminals in distal neuropathy may result in random loss of muscle fibers within the motor unit (16) and this may be the cause of the increase in percentage of normal duration, normal amplitude polyphasic MUAPs observed by the author.
In the patient population studied, the diagnosis of root level involvement was made on the basis of increased incidence (> 30%) of normal duration, normal amplitude MUAPs and also by the presence of increase in the difference in conduction time between the F (soleus) and H-reflex (soleus). This difference was noted to be high when compared to the normal value of less than 3 ms (11). This difference indicated to the author that there were conduction abnormalities along the S1 motor nerve roots. There was a trend for most of these patients to show involvement of 3 or more roots,

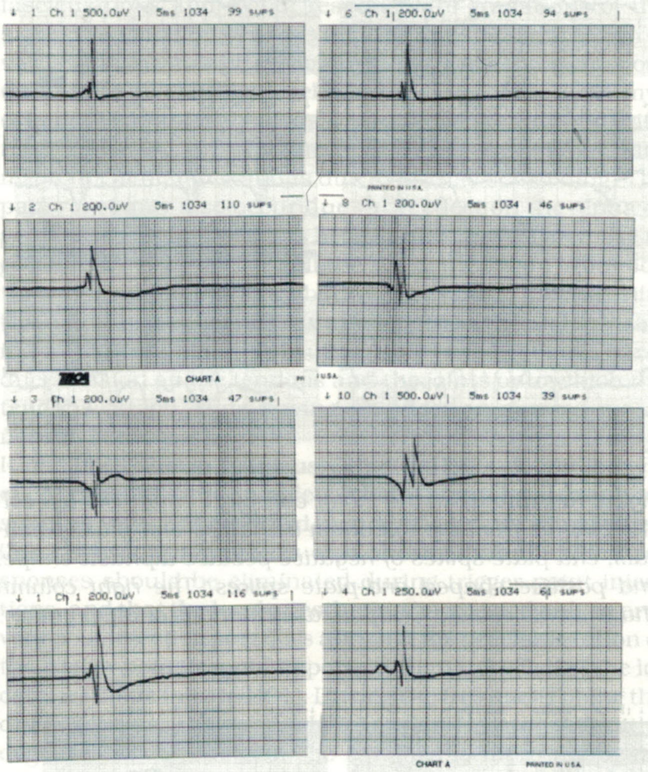

Fig. 1.

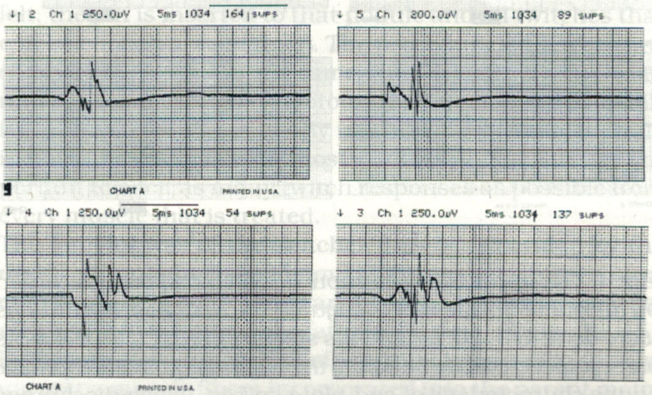

Fig. 2

Figs. 1 and 2. Normal duration, normal amplitude polyphasic MUAPs of varying complexities in shape. MUAPs have been averaged.

usually L4, L5 and S1 roots, with more involvement at the L5 and S1 levels (Table 3).
The MRI scan results were available to the author in only 50% of the patients (Table 5). Among those whose MRI scan results were available, none of the patients had evidence of

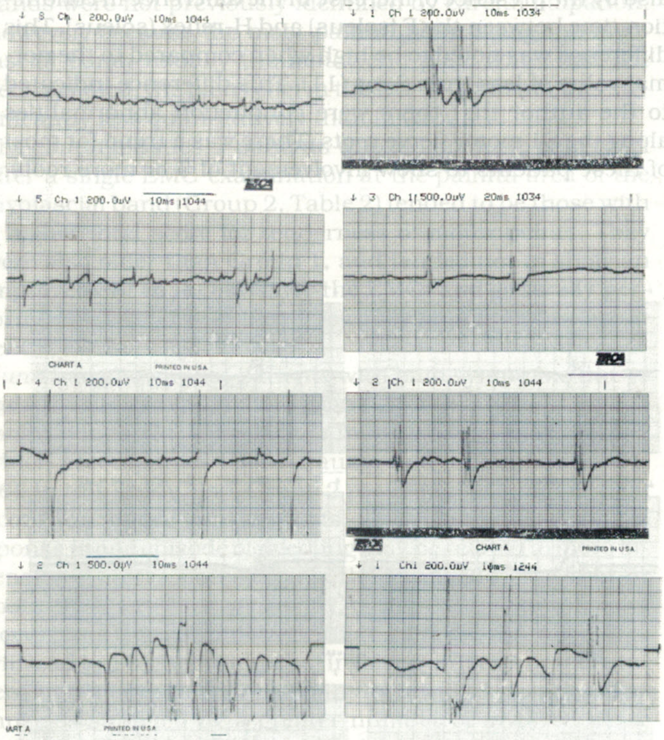

Fig. 3. Recordings at the motor end-plate zone. The left column shows from top to bottom miniature end plate potentials, end-plate spikes of negative-positive diphasic shape, and positive shaped end-plate spikes. The right column show needle evoked grouped fasciculations or myokymia.

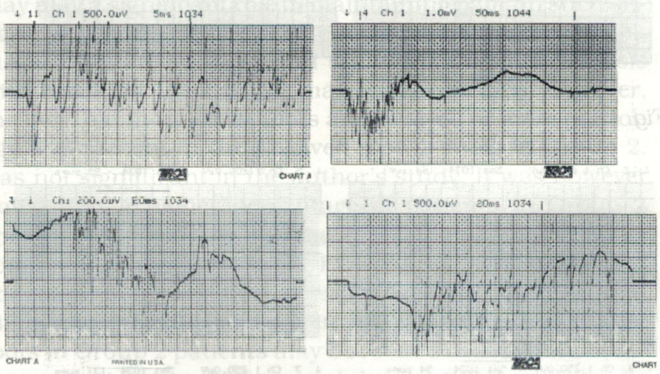

Fig. 4. The upper 3 traces show a twitch response recorded by the same needle that instigated the twitches. Recordings were done at 5, 20, and 50 ms sweep speeds, with the 5-ms sweep speed clearly showing the negative-positive diphasic shape characteristic of end-plate spikes, which discharged in grouped fashion. The lowermost recording was done with a separate needle at the end-plate zone, which recorded the twitch activity instigated by another needle close by to the recording needle. Note the similarity of the potentials record-

compression of the spinal nerve roots. It was note among the patients who did not have MRI scan r available, 2 patients (one from the CG-PR and one Group 1) had spontaneous activity in a myotomal pa The fact that these 2 patients had pain relief with EM dicate to the author that patients showing spontaneo tivity may still achieve pain relief with the IMS effect EMG (see also case report no. 4). The author does n pect either patient to have significant nerve root com sion since the physical examination did not show muscle weakness, dermatomal sensory deficits or t reflex abnormalities. Even though the MRI scan r were not obtainable for 50% of the patients, the autho not expect any of these patients to have significant root compression since none of these patients showed tomal spontaneous activity on EMG and did not have neurological deficits suggestive of nerve root compre on physical examination. It is the author's experienc a careful physical examination of the patients for m tone and tightness, and needle exploration of myof bands for presence of muscle spasm is a better coroll the response to IMS than the presence of bony or di normalities noted on the MRI scan.

Relating to IMS and effects on pain

The nerve supplying the muscle, enters the muscle end-plate zone. The location of the end-plate zone be more precise when the most tender point along the m band is located first. Needling of the end-plate zone stimulate both motor and sensory fibers since only 60% of the fibers are efferent and the rest of the nerve

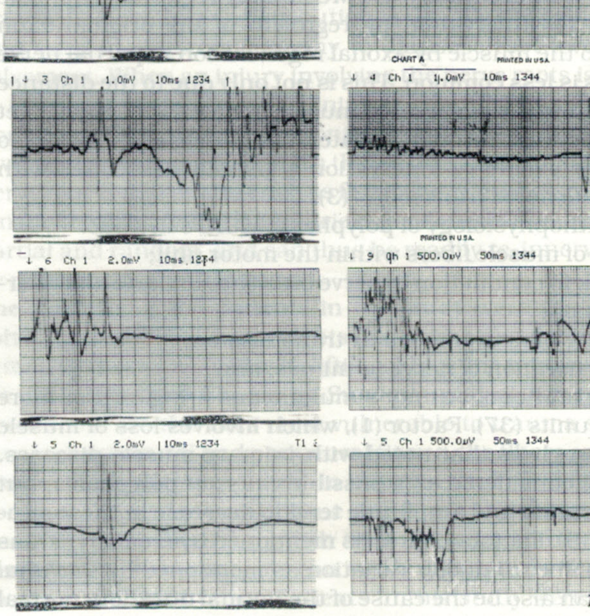

Fig. 5. Twitch responses instigated by a first needle corded with a second needle close by to the first needle end-plate zone. These twitches may be in the form of or grouped fasciculations, or grouped end-plate spike

are afferent (40). The pin penetration of the tender points along the myofascial bands showed that these points are frequently the motor end-plate zones where miniature end-plate potentials (MEPPs) and end-plate potentials (EPPs) are encountered by the EMG needle electrodes. The patients would characteristically complain of a burning pain accompanied by a deep, dull and aching pain which is often referred. Occasionally the pain may be sharp when accompanied by a twitch response. These points have the characteristics of trigger points as defined by *Travell* and *Simons* (59, 60) and needling or palpation of these points may also give rise to autonomic responses. The intramuscular needle triggers potentials in the motor axon terminals or preterminals, or disrupts nearby muscle fibers. The latter releases potassium into the extracellular space and depolarizes the nerve terminals. Both mechanisms could increase the MEPP frequencies. This will cause suprathreshold EPPs (which in turn) trigger post synaptic single muscle fiber action potentials (5).

The author thus proposes that the definition of the trigger point could also be modified to include the fact that these points are motor end-plate zones and when needled the electrical phenomena would range from MEPPs, EPPs, fasciculations, and myokymic discharges to twitch responses (Figs. 3 to 5). Clinically, large twitch responses can be seen and felt. The discharge of these potentials, especially that of the twitch responses will produce alteration of muscle fiber length and tension. Thus stimulation of large diameter muscle afferent fibers will occur producing a pain relieving effect through influence on the gating mechanism as described by *Melzack* and *Wall* (43). A change in total length as well as the rate of change in length of the muscle fibers is detected by the group Ia fibers, and the total change in length is sensed by the Group II fibers. The threshold tension required to excite the Ib fibers is lower when excited by muscle contraction rather than by stretching. Group Ib afferent fibers thus stimulated by muscle contraction will participate in the disynaptic inhibition of the motor neurons supplying the parent muscle. As feedback occurs to the spinal cord and alpha and gamma motor neurons, coactivation occurs and a new homeostasis is maintained with the muscle at a new steady-state length (19, 40, 42). An increase in length of the muscle fibers will thus cause dispersion of nociceptors.

Denervation supersensitivity has been described by *Cannon* and *Rosenbluth* (10). It has also been shown that any measure that blocks the flow of motor impulses, and deprives the effector organ of excitatory input for some time, can cause "disuse supersensitivity" in that organ and in associated spinal reflexes (53). With supersensitivity, the nerves and muscles become overly sensitive and react abnormally to stimuli (1, 10, 22, 63). The presence of denervation supersensitivity and disuse supersensitivity may have permitted mechanical provocation by the needle to easily cause discharge of end-plate spikes and single muscle fiber discharges in sustained or in grouped fashion. This was noted especially at the tender areas along the myofascial bands. These discharges are often accompanied by fasciculations, myokymic discharges and twitch responses (Figs. 3 to 5).

Pain may occur from the increase in muscle tone brought about by sympathetic activation of the intrafusal fibers of the muscle spindle. This will increase the muscle tension or induce muscle contractions via the monosynaptic stretch reflex (20, 40). The chief reason for the pain is caused by supersensitivity of blood vessels and/or nerves to sympathetic transmitters rather than an increase in sympathetic flow (14, 51). Therefore, IMS, which causes muscle relaxation and hence muscle lengthening, will decrease tension on the neurovascular hilus causing a desensitization effect on the sympathetic efferent fibers in the arteriolar walls. In addition, the muscle is also released from having to contract under ischemic conditions and the vicious cycle that maintains the spasm may be eliminated.

In the EMG study, the extent of number of twitch responses obtained in a muscle were not specifically evoked by needling the myofascial bands, but twitch responses were frequently noted visually and were palpable in many of the muscles while performing the EMG. Occasionally, the twitch may be strong enough to cause a sudden movement of the joint, especially at the ankle, usually catching the patient and examiner by surprise. The author believes that the presence of sustained or grouped end-plate potentials, fasciculations and twitch response are gradations of the same phenomenon of achieving focal muscle contraction of varying forces at a physiological level. Stretching thus occurs at the myofibrillar level with breaking of the actin-myosin bonds responsible for sarcomere shortening and stiffness. This in, turn, reduces the pain associated with mechanical manifestations due to muscle shortening. The pain relief may also occur due to an effect on the alpha or gamma activity since it has been shown that an increase in gamma activity may occur if the site of the lesion is outside the muscle, e.g., in a neighboring joint (17, 27). By causing the treated muscles to relax and lengthen through obtaining twitch responses, the author may have been able to reduce tension on the tendons and the joints onto which the tendons attach, thus having an effect on gamma motor neuron activity.

It has been shown previously that patients do not experience immediate and complete relief of pain if local twitch responses were not obtained during trigger point injections (30). Subsequently it was also shown that all twitch responses should be eliminated during trigger point injections, and that the local anesthetic was injected only to prevent post injection soreness and that the precise location of the trigger point is more important than the effect of the local anesthetic injected (31). During the treatment using the dry needling or IMS method, the author has noted that the degree of forcefulness of the twitches is more therapeutically important than the number or frequency of the twitches elicited during treatment. At every tender point along the myofascial band especially when a nodule can be felt, the pin is inserted to that nodule and all twitches that can be elicited are obtained. The procedure is then repeated at another point in the same muscle, as well as in other muscles from the same myotome, and in muscles from different myotomes. Frequently treatment is given bilaterally in the same session to the most involved myotomes. It is important to elicit as many twitch responses as possible from every muscle that is treated.

The forcefulness of the twitches may be generated by the needle stimulating large diameter axons that supply a larger area of end-plates. Large area end-plates are usually associated with large, fast-fatigue muscle fibers (8, 15). Pathologically, stimulation of a terminal nerve twig supplying many muscle fibers incorporated into the parent motor unit by collateral re-innervation could occur. Antidromic stimulation of large motor neurons by the peripheral stimulus may also explain the forcefulness of the twitches and the mechanism could be similar to that of obtaining an F-response. Antidromic stimulation of the motor neuron at the axon hillock may may occur since this has been previously described with immature nerve sprouts (63). Monosynaptic reflex stimulation of large motor neurons by activation of the muscle spindle and hence the Ia afferents may also explain the forcefulness of some of the twitches. Ephatic stimulation of muscle fibers may also be a cause since studies with ischemic radial nerve block, or with brachial plexus injury, seem to still maintain some twitch responses (28, 29).

It has been noted that a significant number of the small diameter axonal sprouts that develop at the site of axonal injury will continue to show abnormal responsiveness and a tendency to after-discharge, even after maturation, to form an approximately normal peripheral nerve that has reached the target muscle. These immature nerve sprouts may also be highly mechanosensitive, with a sensitivity to sympathetic activity (63) and may be the source of the twitches when stimulated by the needle.

The importance of the twitch responses is that the twitches can be used for treatment purposes. The more forceful the twitches the more the pain relief, and the greater the therapeutic effect. The twitches are also diagnostic since they will be most noted in the myotomal distribution of all involved roots. The highest number of twitches are noted in the muscles supplied by the most involved nerve root and the twitches will also appear in a rapid fashion. As the pain improves, the twitches reduce in number, force and frequency. The vicious cycle of "contraction-ischemia" as described by *Simons* (54) has thus been interrupted. The twitches would cause sarcomere lengthening and release the energy consuming contracture that led to tissue ischemia, metabolic deficiency and energy crisis. Large muscle fibers have a poor capillary supply which can further be impaired by muscle spasm. When myofibrillar relaxation is achieved, a positive chain of reactions occurs with less mechanical tension on the nerves, blood vessels, tendons, joints and ligaments. An improvement in microcirculation which has previously been restricted by focalized muscle spasm also occurs. Occasionally, areas of fibrosis within the muscle are encountered. These are called "invisible lesions" (25) since these are not noted even on the MRI scan. When such areas are encountered multiple penetrations with the pin are performed in order to cause micro-inflammation as well as focal destruction and dispersion of nociceptors in that region.

The mechanism of pain relief also involves the current of injury with the negativity at the site of injury (34) which has biological influences on the underlying tissues. Experiments in the laboratory have shown enhanced nerve growth toward the negative pole of a weak direct current field (33, 47, 48, 49). Replacement of the needled areas by microfibrosis also occurs, thus displacing the number of nociceptors (23).

It has also been shown that acupuncture points and trigger points are similar (18, 44). It is the author's experience that these points are indeed motor end-plate zones. In such situations, the effect of the intramuscular stimulation is sufficient to reduce the pain and thus no injections are needed as proposed in trigger-point injections (59, 60). In fact, trigger-point injections may counter the physiologic effects of obtaining twitch responses and the resultant effects on the spinal cord and central nervous system through reflex pathways.

Pain relief may occur through "hyperstimulation analgesia" by stimulating small fibers that could bring about an

brainstem reticular formation. This has a power
tory control over pain transmission at all levels c
ral axis (44, 45). This seemed to be the situation
relief was noted in the CG-PR patients where EM
formed at random sites, not necessarily targete
tender areas in the myofascial bands. The prolo
of pain may be due to massive input produced b
dling, which has a disruptive effect on prolonged
atory activity in neuronal circuits which ma
"memories of earlier injury" (41, 45). Patients a
function better due to the decreased pain, which
proprioceptive input that prevents the resump
abnormal reverberatory activity that underli
pain.

The dry needling may also produce endorphins
acupuncture points may be the same as the ter
that the author has chosen along the myofascial
acupuncture analgesia has been associated w
phin release (50). However, since the pain reli
from IMS is usually immediate, the author belie
flex mechanisms or antidromic mechanisms du
fect of dry needling of both motor efferents and
ferents at the motor end-plate zones is more
than the effect of endorphins. In addition, the
the post-treatment pain of 1 to 2 days (even up
and subsequent pain relief cannot be explaine
phins only.

There is increased pain after the needling in m
and this is likely to be related to direct mechar
tion of the nociceptors. Sensitization of the noc
neurovasoactive substances and other subs
leased from damaged tissues and (or) blood c
could also occur, resulting in muscle tendern
quate desensitization may occur when the very
ger points where very forceful twitches may be
neglected or inadequately treated. In such cas
should be treated with a minimum amount of n
attempts to elicit the twitch responses initiall
done at the most active trigger points in the m
myotomes only. The most active trigger poin
most tender area in the myofascial band which
dled will give very forceful twitches. The twitc
be high in number and come in rapid success
tient can usually locate these points for the ph

**Relating to IMS as a major therapeutic modal
trol of neuropathic pain**

The IMS technique is a recognized clinical proc
institution and we routinely treat patients
neuropathic pain related to spondylosis using
ty only. The presence of tender myofascial
quantitative EMG can help in documenting t
thic involvement due to radiculopathy. Precis
etration of the trigger points is essential for a
relief. At these points, the fingers manipulati
recognizes muscle spasm by a "sticky doug
"grab" sensation onto the needle. The ultin
muscle spasm is the presence of twitch respo
The total number of IMS treatments and the
treatment may vary according to the age of th
ration of symptoms and number and degree
involvement. Other associated or concurren
affecting muscle function locally or systemica
to the case illustrations) also play a role in
pain relief achieved with IMS. The author's ex

least for the first 5 to 10 treatments. Repeated treatments are continued at weekly or biweekly intervals until the pain relief becomes significant enough to allow the patient to resume a suitable life style. Repeated treatments can be safely done with minimum trauma to the tissues since the needle used is a 30 gauge wire-like disposable pin used for acupuncture. The pin does not have a cutting edge and is injected into the tissues using a plunger. The patients need no formal adjunctive physical therapy, or psychological counselling that is part of the traditional way of treating chronic refractory pain. Spinal surgeries and injections of medicinal substances into muscles, nerves or joints can be avoided if pain can be controlled with a trial of the IMS treatments. Even cases of recalcitrant pain after these other procedures have failed can still be helped with IMS. No adverse complications have been noted using the IMS treatments except for occasional dizziness related to intense painful stimuli given in rapid succession. It is important to let patients alert the physician when the treatment becomes too painful. A transient increase in creatine phosphokinase (CPK) may be noted in some patients when the entire spine and many myotomes may need to be treated in one session. However, the CPK have been noted to return to normal values within 3 to 4 days. The procedure is well tolerated by most patients especially when treatment can be limited to the most symptomatic muscles or myotomes. Some patients may need pre-medication with codeine and a muscle relaxant prior to and after the treatment. Narcotic medications are prescribed usually on an "as needed" basis, and patients previously on narcotics may be able to reduce the dosages as the treatments take full effect. The IMS procedure is done on an outpatient basis and causes no impairment of driving capabilities although a companion is suggested if the patient prefers to take some narcotics for treatment purposes.

The contra-indications for the IMS procedure are similar to that of performing an EMG, namely bleeding diathesis and coagulation disorders, embolic disorders, local and systemic infections and inflammations, and autoimmune deficiency syndromes. A sound knowledge of anatomy is essential for good results and in order to avoid complications such as nerve and blood vessel injuries, and injuries to internal organs by accidental penetration with the pin.

Much more research is needed to understand why the IMS technique is so powerful a tool in reducing pain of neuropathic origin providing there is muscle spasm. It is not of benefit in cases of pain due to severe nerve injury where the muscle is totally fibrotic. It is not a modality for treatment of nociceptive, inflammatory or psychiatric pain. The author proposes that IMS method is very effective and can be used as a treatment of choice for management of acute and chronic neuropathic pain. It is a safe procedure, and is an anatomically and physiologically based pain management technique that can be utilized on a chronic basis without complications.

Illustrative case histories

Case no. 1: A 65-year old obese, hypertensive and diabetic woman was admitted to our Rehabilitation Center on 2/24/92 for management of her chronic neck and LBP. The patient had experienced minimal pain since adulthood in her right hip. Beginning in 1975, the patient developed increasing right hip pain which was attributed to her long history of osteoarthritis of the right hip. She eventually underwent a right total hip arthroplasty in 1985 which was revised in 1987. The pain lessened postoperatively.

However, the patient later developed increasing bilateral lower extremity pain with weakness, and increased cervical and lumbar spinal pain. The myelogram showed herniated nucleus pulposus at C5-C6 with cord compression for which she underwent anterior C5-C6 discectomy and fusion on 1/9/87. She also underwent a bilateral L3 through L5 decompressive laminectomy with bilateral L5 nerve root decompression on 4/29/87 for lumbar spinal stenosis. Her neck pain persisted and in 1988, she was diagnosed to have cervical stenosis and underwent bilateral posterior decompressive C3-C7 laminectomy on 11/14/88. Postoperatively, however, she was found to have mild sensori-motor deficits in her left upper and lower extremities secondary to a pontine infarct documented by MRI scan. Other medical history includes congestive heart failure; hypothyroidism, depression; and anxiety disorder. Previous surgical history included an appendectomy, a tonsillectomy, a cholecystectomy, a hernia repair secondary to right inguinal abscess and bilateral carpal tunnel releases.

The patient was relatively pain free, at least not taking narcotics, until 10/91. She experienced progressive exacerbation of LBP. She also had a radiating, sharp pain to her bilateral lower extremities from the groin down continuously with occasional exacerbations. There was also a burning feeling in both legs attributed to the presence of underlying diabetes. She also had intermittent cervical pain. The patient felt fatigued since her sleep was continuously interrupted by pain even with a sleeping pill. The patient could walk with a cane, 5 to 20 feet, depending on the level of pain on that day. She could stand for 1 to 5 minutes maximum. Regarding activities of daily living, she was unable to wash her lower extremities, and she could not stand long enough to perform meal preparations. The patient became progressively more home bound and sedentary. Her thought processes were preoccupied with her pain and decreased functioning. She was placed on various narcotics without adequate pain relief. At the time of admission, her oral pain medications included morphine sulfate contin (MS Contin) 60 mg every 8 hours and morphine sulfate immediate release (MSIR) 45 mg every 6 hours.

Previous procedures to reduce pain included ice massage, moist heat and ultrasound, TENS unit, trigger point injections, biofeedback, and spinal orthotics none of which gave pain relief to the patient. She obtained minimal relief from pool therapy. The patient's dependency on narcotics was increasing even with in-patient physical, occupational and psychological therapies. The patient was evaluated by the anesthesia pain team but she felt she was too ill to proceed with the proposed treatment plan including injections. Psychiatry was consulted for evaluation of her depression and for possible transfer to the psychiatric unit since the patient was non-cooperative with her physical and occupational therapy programs and was also verbally abrasive with the therapists and nurses. The opinion of the medical staff was that patient's behavior was related to depression and reduced pain tolerance with dependency on Morphine Sulfate.

The author was consulted to evaluate the patient on 3/4/92, at which time a plan was being made to transfer the patient to the psychiatric unit for further management of her chronic pain syndrome and depression. On initial evaluation on 3/4/92, patient was unable to stand erect due to the LBP and needed support for transfers from the wheelchair to the bed. She was unable to lie on her back and left side due to the LBP. IMS treatments were given to the lumbosacral paraspinal muscles, quadriceps muscles and gluteal muscles. Many areas of muscle spasm were noted as well as presence of muscle tissue scarring in the lumbosacral as well as gluteal muscles. Prior to treatment, the patient's supine straight leg raise (SLR) was 25 degrees on the right, 10 degrees on the left. After the treatment, the SLR was improved to 60 degrees on the right and 80 degrees on the left. She was able to move her lower extremity much better on the next day. On 3/6/92, she received the 2nd treatment. The SLR was improved to 80 degrees bilaterally. She then was able to dress lower extremities well including being able to bend down to tie her shoe laces which she said she had not been able to do for at least 2 years. At the same time, the patient stated that she had mild relief from her pain, which was an encouraging new experience. EMG performed by the author showed findings compatible with bilateral symmetrical axonal peripheral neuropathy and slowly progressive as well as very chronic involvement of L2 to S1 nerve roots bilaterally. The patient received her 3rd IMS treatment on 3/10/92 with further improvement in her pain, range of motion of the spine, particularly that of anterior flexion, and ability to function. The hospital course was complicated by the presence of new onset left pontine infarct requiring transfer to neurology service. She also developed a left facial palsy due to her diabetes. She was re-transferred to the rehabilitation center on 4/8/92, and further IMS treatments were resumed at weekly intervals. The patient was discharged to home from the rehabilitation center on 4/24/92 at which time she was able to ambulate independently without assistive devices and was also able to negotiate stairs. She was also able to cook simple meals for the staff in the rehabilitation center during her occupational therapy sessions.

The patient continued to receive IMS treatments initially at twice a week while in the rehabilitation center and then every 1 or 2 weeks directed to the C7-S1 paraspinal muscles and the L2-S1 myotomes at various sessions. Twitch responses were noted in the bilateral L2-S1 myotomes, especially more prevalent in the left gluteus maximus. Noticeable improvement occurred in the range of motion of the lower extremities and spine and in the level of pain. She was able to gradually reduce the MSIR such that she was able to discontinue use of MSIR by 6/1/92. Her LBP as well as the burning pain in the legs were controlled by MS Contin 60 mgm twice a day. The SLR was improved to 90 degrees bilaterally by this time and she was able to sleep 5 to 6 hours with a sleeping pill. She could bend down to clean her bathroom and refrigerator even though she was still unable to cook. She was able to go grocery shopping at a supermarket which was one block away. On 11/13/92, she was able to cook and shop for 2 to 3 hours with little discomfort without using a wheelchair, or a cane. Her IMS treatments were then weaned to 1 treatment every month and her Morphine Sulfate Contin dosage was reduced to 60 mgm once a day. On 12/29/92, on a very snowy and icy day, patient went to her outside mail-box when she slipped and fell on her left hip and sustained an intertrochanteric fracture. She was admitted to a hospital and underwent an open reduction internal fixation of the left hip. Postoperatively, she stayed in the rehabilitation center for 21 days to upgrade her functional status and mobility. Her pain medication at this time was MS Contin 30 mg in the morning, and 60 mg in the evening but required an additional MSIR 45 mg prn due to the left hip pain. Even after she underwent the hip surgery, her mood was not depressed. In fact, she remained motivated and optimistic about her recovery throughout the hospital

The patient returned for follow-up IMS trea
3/11/93, one and a half months after she was
from the hospital. At that time, her left hip w
completely healed, and she was ambulating wi
with partial weight bearing on the left lower extr
range of motion and functioning were somewh
mised secondary to the healing left hip, but sh
most of her previous level of functioning gradu
recovered. As of 4/15/94, she has been full weig
able to ambulate independently without assist
within the home and with 1 straight cane for o
bulation. Since then, she has been receiving
once a month initially, and then once every 2
control her chronic pain and to upgrade her f
She has remained stable and is on MSIR 60 mg
of 6/30/95, she continues to do well with a trea
three months.

Case no. 2: A 65-year old white male executive
personality, presented to our office on 3/29/9
plaints of low back and bilateral gluteal pain as
down the posterior aspect of both thighs for
There was also pain in the right testicle and pa
lateral aspect of the left foot with numbness al
of the left foot. He states having had the left le
for approximately 34 years. A urological exam
not revealed any testicular abnormalities. Ot
history included a borderline diabetes, hyper
emia and 2 angioplasties in the past. He had b
in marathons since age 51 years and had bee
without difficulty until in the past 3 months wh
get pain in the buttocks and right calf after r
miles. MRI scan of the lumbosacral spine
showed a large central and somewhat more rig
herniation at L5-S1 level and moderately seve
nosis at the L4-L5 due to a combination of
central disc protrusion and hypertrophy of the
or elements. He had sought orthopedic evalua
not considered to be a surgical candidate sin
no motor weakness nor sensation loss. How
advised to have surgery when his numbness i
there was weakness which limited his walking
with his life style.

Physical examination on the initial visit show
of lumbosacral spine range of motion in ant
extension and lateral flexion. The FABERE te
to flex, abduct and externally rotate the hip) w
laterally. The cervical spine range of motion w
ed on flexion, extension, lateral flexion and lat
particularly for lateral flexion and lateral ro
right. Limitation of shoulder range of motion
external and internal rotation especially for i
tion of both shoulders. The right shoulder an
were higher than the corresponding points o
He had only very minimal tenderness to pa
motor points of the C2 through C8 myotomes
L2 through S1 myotomes. No focal motor we
flex asymmetries were noted, but numbnes
was present along the lateral border of the lef
The EMG studies performed by the author s
onset and ongoing radiculopathy of the bilate
nerve roots especially along the left L5 and
roots. Chronic changes are also noted along t
through S1 nerve roots. During treatment, tw
es were noted in the right and left L2 through S
The right L5 myotome and the left S1 myotom

to be most involved where the right tensor fascia latae muscle elicited as many as 96 twitches and the right gluteus maximus elicited as many as 108 twitches in 1 treatment session. Other muscles in the involved myotomes exhibited between 7 to 50 twitches. Twitch responses were also noted on treatment of the upper limbs in the distribution of the right C3 through C7 myotomes, especially in the right C4, C5 and C6 myotomes where the number of twitches ranged between 10 to 14 twitches.

After the first treatment on 3/29/91, patient was able to run 5 miles without any pain in the buttocks for 2 days and then the pain reoccurred. Weekly IMS treatments were given to include the thoracic and lumbosacral paraspinal muscles, and gluteal muscles. After the 4th treatment, patient had 60% improvement of his pain. Original complaints of pain in the right testicle disappeared by about the 8th treatment. He continued jogging for 1 to 2 miles and felt that his low back was fragile and was advised not to jog or run. By the 20th treatment on 8/14/91, his pain had been reduced from 7 to 8/10 to 1.5 to 2/10 level and he resumed running less than a mile. He was able to walk 3 miles without any pain. He was then treated once every 2 weeks as of 11/6/91. He was able to run up to 3 miles with mild discomfort only. By the 24th treatment on 11/11/92, he had no complaints of buttock pain and had occasional LBP while running and his treatments were reduced to 1 treatment every 3 weeks. By the 40th treatment as of 9/1/93, his treatments were spaced to 1 treatment every month in order to reduce muscle spasm and tightness so that he could continue running. Since then, he had already completed 3 marathons where he could run for about 3 miles and walk the rest of the way. His physical examination had shown improvement in his ability to anteriorly flex the spine but his lateral flexion was still limited. The FABERE testing was still limited bilaterally but showed definite improvement. His pain level after running is rated at 3/10 level, otherwise he remains pain free. He feels that his condition has been satisfactorily controlled and continues walking 17 miles/day over the week-ends but is unable to run more than 1 mile due to increased numbness in his left foot while running. A repeat MRI scan on 7/6/94 showed essentially no changes to that performed on 5/30/91. He continues to do well with monthly treatments as of 6/30/95.

Case no. 3: A 36-year old white female, with no prior medical history presented to the author for electrodiagnostic testing on 12/10/91, for determination of the cause of continued LBP after an auto accident on 11/18/85. She was a passenger on a transit bus that was involved in a collision with a truck. Patient was thrown from her seat to the floor of the bus. After the accident she started to have LBP and numbness that radiated down the entire left lower extremity to the left foot. Other symptoms included numbness down the lateral aspect of the thighs with numbness in the last 4 digits of both feet as well as pain in both upper extremities and across the front of the chest and along the back of the neck. She also had complaints of some numbness in the face. She sustained a C6 compression fracture related to the accident. CT scan on 3/24/86 showed no evidence of disc herniation or spinal stenosis in the lumbosacral spine as well as in the cervical spine. She continued with LBP and was given an MRI on 9/26/90, which revealed disc degeneration with disc space narrowing and vertebral end-plate sclerosis with a focal somewhat prominent left-sided disc herniation with nerve root compression at the L5-S1 level. She was given a lumbar epidural anesthesia for pain control to which she had no positive response. She was then operated for a left lumbar discectomy for a herniated nucleus pulposus at L5-S1 level on 1/30/91. She had no pain relief after the surgery and started to have more pain down the left lower extremity than prior to the surgery. She also complained of frequency in urination (1 every hour) and increased bowel movements (3 to 10 times/day) since the surgery. She had frequent episodes of nausea and vomiting, dizzy spells on neck extension, irritability and depression. She was able to ambulate slowly and painfully using a cane in the right hand, with most of her weight distributed on to the right leg. She had tried various forms of physical therapy as well as chiropractic treatments without any relief of pain. She was discouraged since she was taking medications that included Demerol 300 mg a day, Inderal 40 mg a day and Valium 10 mg daily as well as a sleeping pill as prescribed by her family physician. She had difficulty sleeping and was awakened 3 to 4 times at night due to her pain. Other relevant history included left leg sciatica in 1984 with complete pain resolution within 1 month.

The EMG studies revealed recent onset and ongoing radiculopathy of the L5 and S1 myotomes bilaterally of grade 2 severity. Underlying chronic involvement was also noted in muscles supplied by L4 through S1 nerve roots bilaterally especially the bilateral L5 and S1 nerve roots, more chronic along the S1 nerve roots. No involvement was noted along the L2 and L3 nerve roots. The nerve conduction studies showed the amplitudes of the evoked motor responses along the left peroneal and tibial nerves to be significantly smaller than that noted on the right side. The H-reflexes were also depressed bilaterally, moderately on the left side and mildly on the right side. Significant differences were also noted bilaterally between the F-response (soleus) and H-reflex (soleus) which the author interpreted as compatible with conduction delay along the S1 motor nerve roots bilaterally. Otherwise the nerve conduction studies were normal.

After receiving the EMG, the patient returned our questionnaire and stated that she had 20% pain relief and was interested in returning for treatments as soon as she was able to pay for the treatments if and when settlement occurred on the impending lawsuit. She returned for her first intramuscular stimulation treatments on 5/27/92, nearly 6 months after the EMG. She still ambulated with a straight cane in her right hand with minimal weight bearing on her left lower limb. She was unable to bend backwards or forwards and was unable to stand with weight bearing only on the left lower extremity without the support of the cane. Even while in a sitting position, she was unable to lift her arms up beyond the horizontal. Paraspinal spasm was noted bilaterally from the C5 through S1 levels, more on the right than on the left. Significant tenderness was noted on palpation of the cervical, thoracic, and lumbosacral paraspinal muscles as well as the motor points of the L2 through S1 myotomes. Tenderness was more significant on the left side. Palpation of the tender motor points was accompanied by significant vasomotor changes and sudomotor changes. Trophic neurogenic skin changes were noted as large pores in the skin overlying the paraspinal muscles as well as trophic neurogenic edema was noted in the L4, L5 and S1 myotomes. The reflexes were symmetrical bilaterally and the plantar reflexes were down going bilaterally. Her straight leg raising testing was 20 degrees on the right and 15 degrees on the left and she had significant limitation on performing the FABERE testing. IMS treatments were given from the C7 through S1 level paraspinal muscles bilaterally as well as to the bilateral trapezius muscles. Treatments were also given to the bilateral L5 and S1 myotomes. After the first treatment on 5/27/92, patient felt significant relief, "as if a miracle had been performed". For 2 to 3 days after the treatment, she had excellent pain relief such that she tried to take a bath since she had been unable to tolerate sitting in a bathtub and had taken only showers for at least one and a half years. She unfortunately developed tremendous low back spasms from maneuvering to sit in the tub. When she returned for the second intramuscular treatment on 6/4/92, she was in severe acute pain. IMS treatments were given to the bilateral paraspinal muscles from T10 through S1 levels as well as the left L2 through S1 myotomes. Her oral Demerol usage was increased to 300 mg 3 times a day but without significant pain relief. She was given a trial of MS Contin but was unable to tolerate the side effects of dizziness and nausea after two 30-mgm doses.

With the first 2 treatments, since she was in severe pain, the treatments were excruciatingly painful and she needed premedication with oral Demerol. By the third treatment on 6/17/92, she was able to tolerate the treatments better. The cervical to the sacral level paraspinal muscles were addressed on the third treatment. After the 4th treatment on 6/17/92, she was able to reduce the Demerol dosage to 200 mg 3 times a day. Her pain level had reduced from a level of 9/10 to 6/10 level. She also showed an improvement in ability to do the FABERE testing. Treatment directed towards the cervical myotomes showed twitch responses in the bilateral C5 and C6 myotomes. Twitches were also noted in the bilateral L5 and S1 myotomes. By the 6th intramuscular stimulation treatment on 7/8/92, she felt that her legs had become stronger and she was able to sleep at least 4 to 5 hours at night. She was able to walk in a straighter posture and needed less pressure on the cane. Straight leg raising testing was increased to 35 degrees on the right and 25 degrees on the left. A mild increase in strength was also noted in the extensor hallucis longus muscles. Twitches were noted in L4-S1 myotomes. By the 7th treatment on 7/22/92, most of the pain in the legs had subsided, but the LBP and the neck pain continued at a high level. She was also able to ambulate within the house without using the cane but close to the walls in case she lost her balance. The strength of the extensor hallucis longus on the right also increased to 4/5 level from previous 3+ level. By the 8th treatment on 8/12/92, patient was able to tolerate her pain without taking Demerol for at least 2 days a week. After the 9th treatment, she began to experience some LBP relief. Two weeks later, after the 11th treatment, she was able to walk 2 to 3 blocks with less pain and her steps were more brisk. Urinary frequency had also reduced to 1 in every 2 hours. Her diarrhea still persisted. She was also able to reduce the Demerol to 100 mg 3 times a day. Treatments were given regularly to the C2 through S1 paraspinal muscles and C2 through C6 myotomes and the L2 through S1 myotomes. By the 12th treatment, she was able to walk at least 2 blocks without the use of her cane. Twitch responses continued to be noted in the left L2 through S1 myotomes as well as in the left C2 through C6 myotomes. After the 15th treatment, she was able to ambulate outdoors without the use of her cane. The urination frequency was now at every 3 hours. The diarrhea was also improved and occurred only twice a week. Twitch responses were

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roots and the left L5 and S1 nerve roots. The L5 and S1 nerve roots bilaterally were more involved, more on the right side, especially along the right S1 nerve root. Large amplitude positive sharp waves and fibrillation potentials compatible with active denervation were noted at the right L5 and S1 level paraspinal muscles. Evidence also of moderately severe very chronic reinnervation changes were noted at the bilateral L4 through S1 nerve root levels especially the L5 nerve root and mild to moderate chronic changes noted at the L2 and L3 nerve root levels bilaterally. Some of the chronic MUAPs were as large as 20 mV in amplitude. The H-reflexes were noted to be absent bilaterally and the F-responses (soleus) along the tibial nerves were also delayed bilaterally. The amplitudes of the evoked motor responses along the peroneal nerves bilaterally were small, otherwise peripheral nerve conduction studies along the bilateral peroneal, tibial and sural nerves were normal.

The physical examination showed moderate limitation of lumbosacral spine range of motion on anterior flexion, extension and lateral flexion more to the left, due to more pain on the right side of the back. The straight leg raising testing was 50 degrees on the left and 45 degrees on the right. The right shoulder and pelvis levels were higher than the corresponding points on the left side. Mild weakness was noted on strength testing of the extensor hallucis longus muscles bilaterally (3+/5). Patient showed weakness on dorsiflexion and plantarflexion of both ankles when tested with weight bearing only on the lower extremity that was being examined. The Trendelenburg testing was positive bilaterally. There was tenderness to palpation of the paraspinal muscles as well as on palpation of the motor points of the L2 through S1 myotomes. Paraspinal spasm was noted bilaterally from T7 through S1 levels more on the right than on the left. Trophic neurogenic pitting edema was noted in the L2 through S1 myotomes. Reflex testing showed sluggish reflexes in the right upper extremity, questionably present knee jerks bilaterally and absent ankle jerks bilaterally. The plantar reflexes were down going bilaterally. There was no reduction in sensation testing and the joint position and vibration sense were normal.

After the EMG examination, the patient had significant pain relief such that he was able to discontinue taking any pain medications. However, he still felt weak in his lower extremities and had an episode of a fall onto his knees prior to the actual IMS treatment on 5/28/93. On examination on 5/28/93, he was able to perform the straight leg raising to 65 degrees bilaterally which was an improvement from the examination prior to the EMG. Patient was able to perform only half of a squat using medium support. There were no changes in the plantarflexion and dorsiflexion strength. The FABERE testing was moderately limited bilaterally. IMS treatments were given to the bilateral C7 through S1 level paraspinal muscles as well as the right L2 through S1 myotomes and the left gluteus maximus, gluteus medius and tensor fascia latae muscles. During treatment, twitch responses were noted in the distribution of the right L2 through S1 nerve roots especially along the right L4 through S1 nerve roots specifically in the right tensor fascia latae and the bilateral gluteus maximus muscles. After the treatment, patient had a significant improvement in ability to do the FABERE testing on the left side but not on the right.

The patient returned for the 2nd treatment on 6/23/93 stating that he had relief of the LBP but there was still some pain in the right lower extremity such that he had fallen to his knees, and felt weak in his knees especially on going down steps. IMS treatments were given to the right L2 through S1 myotomes and the left gluteal muscles. During treatments, many forceful twitches were obtained from the right vastus medialis (42) and from the right tensor fasciae latae muscles (51). After the treatment, the patient had significant pain relief and his FABERE testing improved bilaterally. Patient returned for the 3rd treatment on 6/19/93 again stating that he had fallen 2 times in the past week. He also felt weak in both knees and there was pain in the back of the right knee. Straight leg raising testing was 50 degrees bilaterally and the FABERE testing was more limited than after the last treatment. Treatments were given to the right L5 and S1 myotomal distribution and twitch responses were noted in most muscles of these myotomes. After the 3rd treatment (approximately, 5 weeks from the onset of pain), patient had such significant pain relief that he felt no need to return for further treatments. He did not have pain that interfered with his activities of daily living. He kept his balance by walking slower than usual and did not feel the need to use a cane although this was suggested. He has been able to continue with research work and go to his laboratory daily using public transportation independently. He has also successfully gone on international trips involving 18-hour air flights without problems. His functional status has remained stable and he has not required any treatments for the past 24 months.

Case no. 5: Patient is a 46-year old female nurse, with no significant medical history, who complained of LBP after twisting and turning to transfer a patient from the bed to the wheelchair on 2/25/93. She felt electric pains in the left side of the low back and buttock to the left hip joint region. She was diagnosed as having a left sacroiliac joint involvement by a spine specialist and was ordered physical therapy 3 times/week. When she had no significant pain relief, she was given 2 sacroiliac joint blocks in 6/93. This alleviated her pain for about 2 weeks from a level of 9/10 to 2/10, after which the low back and buttock pain returned to 4/10 level. She decided to return to full time work on 6/21/93 for financial reasons. On 7/26/93, her pain became continually worse. On the day of presentation to the author's office on 8/1/93, she was unable to go to work because of intense LBP. Pain was described as mainly in the left lower back, bilateral upper buttocks and left sacro-iliac region as well as along the lateral aspect of the left hip. She also complained of numbness of the left thigh and leg. Most activities of daily living would aggravate her pain. She had no bowel or bladder complaints. She was taking Relafen 500 mg twice a day without significant relief.

The physical examination showed the patient to be in obvious distress due to the LBP with difficulty in sitting, standing and bed mobility. Pain level was rated as 9/10. Moderate limitation of range of motion of the lumbosacral spine was noted for anterior flexion, extension and lateral flexion especially to the right due to presence of significant LBP on the left side of the back. Straight leg raising testing was limited to 55 degrees on the left and 70 degrees on the right. The left shoulder and pelvis levels were higher than the corresponding points on the right side. No focal muscle weaknesses were noted. The Trendelenburg testing was positive on the left side. The FABERE testing was moderately limited bilaterally. The patient was unable to squat even when asked to hold on to the examination table. Palpation of the paraspinal muscles showed 3+ spasm in the T7 through S1 levels bilaterally more on the left side. Tenderness was not-

ed on palpation of the paraspinal muscles as well as in the L3 through S1 myotomes bilaterally. Trophic neurogenic skin changes were noticed as significant hair loss in the L4, L5 and S1 dermatomes as well as large pores in the skin overlying the paraspinal muscles. Trophic neurogenic pitting edema was also noted in the L3 through S1 myotomes. The author's impression at that time was that of acute exacerbation of chronic LBP due to bilateral, multiple level lumbosacral radiculopathy, left side being more involved. There was no clinical evidence of left sacroiliac joint dysfunction but that pain in this area was primarily related to low back and the left buttock pain. Past history includes a first episode of LBP and left lower extremity pain after a similar work related injury in 1989. She had physical therapy for 4 weeks at that time. She was also involved in a motor vehicle accident in 1990 which caused the back pain to recur but pain resolved after 4 weeks.
IMS treatments were given to the bilateral paraspinal muscles from T10 through S1 levels as well as bilateral gluteus medius and gluteus maximus muscles. During treatment, forcible twitch responses were noted in the bilateral gluteus medius muscles indicating ongoing irritation of the bilateral L5 nerve roots. The straight leg raising testing after the treatment showed an improvement of the left side to 70 degrees, the right side was unchanged. Ability to plantar flex the ankles was also significantly increased. She also stated having immediate pain relief.
MRI scan of the lumbosacral spine on 8/5/93 showed several small Schmorl's nodes at all lumbar levels and, degenerative disease and small marginal osteophytes at L3-L4, L4-L5 and L5-S1 levels. At L3-L4, there was moderate facet disease with facet hypertrophy, the right greater than the left. No nerve root impingement or foraminal stenosis were noted at this level. At L4-L5, there was mild facet disease with mild foraminal stenosis on the right and at L5-S1 level there was facet degenerative changes at the sacral end-plate with mild foraminal stenosis on the right inferiorly by a small osteophyte. There was no evidence of disc herniation or nerve root compression. An EMG study on 8/30/93 showed recent and ongoing radiculopathy of the bilateral L3, L4, L5 and S1 nerve roots with more involvement along the bilateral L5 and S1 nerve roots, more on the left side. Underlying chronic changes were also noted in the bilateral L2 through S1 nerve root distributions.
After the first IMS treatment on 8/4/93, she had 30% pain relief. The anterior spine flexion and lateral flexion of the spine improved by 65% and 75% respectively. She was also able to squat. She was then given weekly treatments to the paraspinal muscles and the bilateral gluteal muscles. Continued treatments with the IMS showed forceful twitches in the bilateral gluteus maximus and gluteus medius, left tensor fascia latae, right quadratus lumborum muscle (17), as well as in the left L2-L4 myotomes. She continued to show twitches especially in the gluteus maximus muscles for many consecutive weeks. The treatment on 10/20/93 of the left gluteus maximus showed as many as 100 twitches and in the left gluteus medius 65 twitches. The pain level continued to be at 3/10 but due to financial pressures she returned to work on 11/9/93; however, but after 2 days, the pain was so significant that she discontinued working. Treatment on 11/19/93 showed twitches in the left gluteus maximus to be up to 163 twitches. On 11/24/93, she was involved in a significant auto accident in which her car was struck on the driver's side while she was driving. She struck her left chest against the arm rest fracturing the 4th,

especially with body movements. On examinati
neck range of motion was limited in all directions as
moderate limitation of all ranges of motion of both
ders was noted, especially on the left side. Par
spasm was noted bilaterally in the neck muscles w
derness to palpation of the paraspinal muscles as
the motor points of the C2 through C8 myotomes. S
placed on Percocet 1 tablet every 6 hours by the em
room physician and her orthopedic surgeon gave
ger point injections for pain in the left rib cage reg
this did not give her any relief. She returned for IM
ments on 12/17/93, and treatments were given t
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sponses were noted in the left trapezius, left rh
major, left teres major (32) left latissimus dorsi (25
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ceps muscles. These findings indicated current on
ritation of the left C4 through C6 nerve roots and t
eral C7 nerve roots. Patient had significant pain re
the IMS treatments for her neck and shoulder gir
cles. A total of 5 treatments were directed towards
vical spine and bilateral shoulder girdle after whi
ments were found not to be necessary since she
more complaints of neck or chest wall pain. The
also intensified due to the auto accident and she
tinued on weekly treatments directed towards th
sacral spine and lower extremities. Ongoing irritat
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nerve roots, especially for the left S1 nerve root. O
isode, 2/16/94, the twitch responses in the lef
maximus were noted to be as high as 185 twitches
ued treatments were given such that she could
half-time work daily as of 4/4/94. She now began
in a light duty nursing administrative position.
level is stabilized at 2/10 and after 35 treatments
been weaned to treatments every 2 weeks. For the
she has remained stable requiring a treatmen
months.

Acknowledgements

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of case history no. 1.

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