ELECTROPHYSIOLOGICAL AND HISTOPATHOLOGICAL EVALUATION OF CAUDA EQUINA COMPRESSION IN DOGS OBTAINED BY POSTERIOR BONE BLOCK PLACEMENT

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ABSTRACT :

In this study 6 healthy dogs were examined after laminectomy and cubic bone block placement at Animal and Research Laboratory of Social Security Hospital. The cubic bone was removed at the 5th second, 1st minute, 3rd week or left indefinitely. The somatosensory evoked potentials of the dogs were monitorized with Cadwell Quantum 84 equipment intraoperatively and at the postoperative 3rd week. After sacrification of the dogs, cauda equina samples were examined histopathologically. Electrophysiological determination was found to be correlated with duration of the cauda equina compression. Moreover, histopathological neuronal destruction and fibrosis were also in correlation with clinical findings. We concluded that electrophysiologic findings of the patients with spinal stenosis or cauda equina compression could determine the benefits of surgery before decompression planning.

Key Words: *electrophysiology, cauda equina, compression, posterior.*

INTRODUCTION

Spinal stenosis is a clinical situation in which bone and soft tissue narrows the spinal canal and restricts the space for neural elements. Major symptoms are pain and neurogenic claudication (11). After the development of radiology, new data about the paralysis as a result of bony obliteration of spinal canal, began to be published. Syndrome couldn't be described very well, till 1949, when Verbiest stated the modern description (8). After a lot of study about the etiopathogenesis and clinical picture of this sydrome, new treatment modalities have developed. But, there is still arguement about timing and type of the treatment.

First animal model, concerning with spinal stenosis was developed by Delamarter in 1990. In this study, spinal stenosis was evaluated histopathologically and electrophysiologically (1). In 1994, Kim et al. searched for the correlation between narrowing of the canal volume from 25% to 75% and neurologic disturbance, in their histopathologic and electrophysiologic study done for evaluating the spinal stenosis induced destruction on neural structures (4).

All studies have been done either to evaluate the acute spinal stenosis or to determine the degree of neurologic disorder in relation to the amount of stenosis of the spinal canal until now. In this study, the relation between the electrophysiological and histopathological changes in the neural elements and the duration of the spinal stenosis is investigated with a standardized bone block which is used for spinal canal narrowing. So we developed an animal model for determining the optimal time of decompression surgery which is the one of the topics mainly discussed on spinal stenosis treatment.

MATERIAL AND METHODS

Six healthy male dogs were used. Weights of them were varying between 9-13 kilograms. Four of them were in the study group and 2 were in the control groups. All dogs were 2-3 years old and complete physical examinations were done by veterinarians. All had a two-level lumbar laminectomy and removal of sixth and seventh lumbar laminae to permit access to cauda equina. The dogs were anesthetized with intravenous entobar, 25 mg/kg body weight. After anesthetics had been administered the dog was positioned in ventral recumbency with a pillow, supporting the pelvis. The lumbosacral area was shaved and scrubbed with a povidone-iodine solution. A dorsal midline incision was made from the fifth lumbar spinous process to first sacral level. The superficial and deep fascia were incised and reflected from the lamina anal ligamentum flavum of the sixth and seventh lumbar vertebrae which then were removed to expose the dorsal sac.

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In the literature, spinal canal area is noted to be 15 mm^2 to 30 mm^2 in dogs thus we designed a spinal model in which 50% of spinal canal narrowing is created. Blocks shaped cubic, measured 10 mm x 10 mm x 10 mm from manufactured tutoplast allograft were implanted to dogs as to narrow the canal with an average of 51.1% (41.3%-63.1%). After decompression in a manner, a bone block is impacted to the bone and fixed. None of the bone blocks displaced in the follow-up period. Somatosensory evoked potentials (SEP) and bulbocavernous reflexes (BCRL) were monitorized intraoperatively, before stenosis was created.

SEP records were received by Cadweel Quantum 84 apparatus. Machine has 4 channels and both evoked potentials and EMG can be performed. It also has internal RAM disc. Flexible storage for moving stored waveforms up or down the display screen. Special signal analysis routines for manipulating and analysing collected data to extract information. SEP machine can automatically take the averages of at least 5 different records and store the data. Stimulation is made by means of electric stimulation platin needles. Recording is performed by means of surface electrodes. Stimulation intensity is 70 dBn HL and duration is 100 µsec. Parameters of instrumentation are shown in Table 1. Stimulation of the sciatic nerve in the hind limb was done in bilateral and unilateral sequence and was recorded on four cortical electrodes that were placed over the sensory homonculus. Bilaterally-maximum stimulus was used and visible flutter (muscle contraction) of the limb was always seen before recording.

Table 1. Recording and instrumentation parameters

Stimulation intensity	70 dBn HL
Stimulus duration	100 µsec
Repetition rate	2.11/sec
Gain	4/10 µV/div
Highcut fiter	500 Hz
Low-cut filter	10 Hz
Sweep speed	10 msec/div
Artifact scala factor	2
Averages	200
Rejection	"on"

This produced the standart triphasic cortical-evoked potential curve N1-P1-N2, with N1 representing the largest first upward (negative) deflection, about 15-20 ms after the stimulus. The time (in milliseconds) from stimulation to N1 is referred to as latency. P1 is the subsequent downward (positive) deflection, measured as the point of lowest amplitude after N1, N2 represent the next upward deflection, completing the triphasic curve. Amplitude is defined as the difference (in microvolts) between N1 and P1 (Figure 1).

BCRL was recorded from the concentric needle in either right or left BCRL muscle after electrical stimulation to the glans penis. Needle placement can be confirmed by squeezing the glans penis and observing the contraction of the BCRL muscle. Several reflex responses were recorded and the shortest latency was measured.

In this study the osseous blocks were placed in spinal canal for a short period in two dogs. In one dog for 3 weeks and the other for 3 months. Osseous block was suddenly implanted and removed after 5 seconds in the first of 4 dogs. Aim of this experiment was to create an experimental model for evaluating the neurologic deficit phenomen that occured during spinal instrumentation by accidental malposition of implant or probe which may occur to every spinal surgeon. After laminectomy, a bone block was quickly put over spinal canal, kept there for five seconds and suddenly taken away.

In the second, osseous block was implanted for 1 minute and removed. Aim was to create an experimental model for evaluating the injury that is performed by malposition of a hook or a screw or retropulsed bone fragments. Bone block was put over cauda slowly, kept there for one minute and suddenly taken away.

In the other two dogs the osseous blocks were implanted, wounds were closed and the dogs were waked up. In the postoperative 3rd week, the osseous block was removed from one of the dogs. Aim was to create an experimental model for evaluating subacute spinal stenosis caused by trauma or degenerative disease. The osseous block from the last dog was removed in the 3rd month. For the last dog, we aimed to create an experimental model for chronic spinal stenosis. SEP and BCRL monitoring were repeated in the postoperative, 1st week, 3rd week and 3rd month for all the dogs. All recording were obtained for 3 times and mean values and standart deviations were calculated.

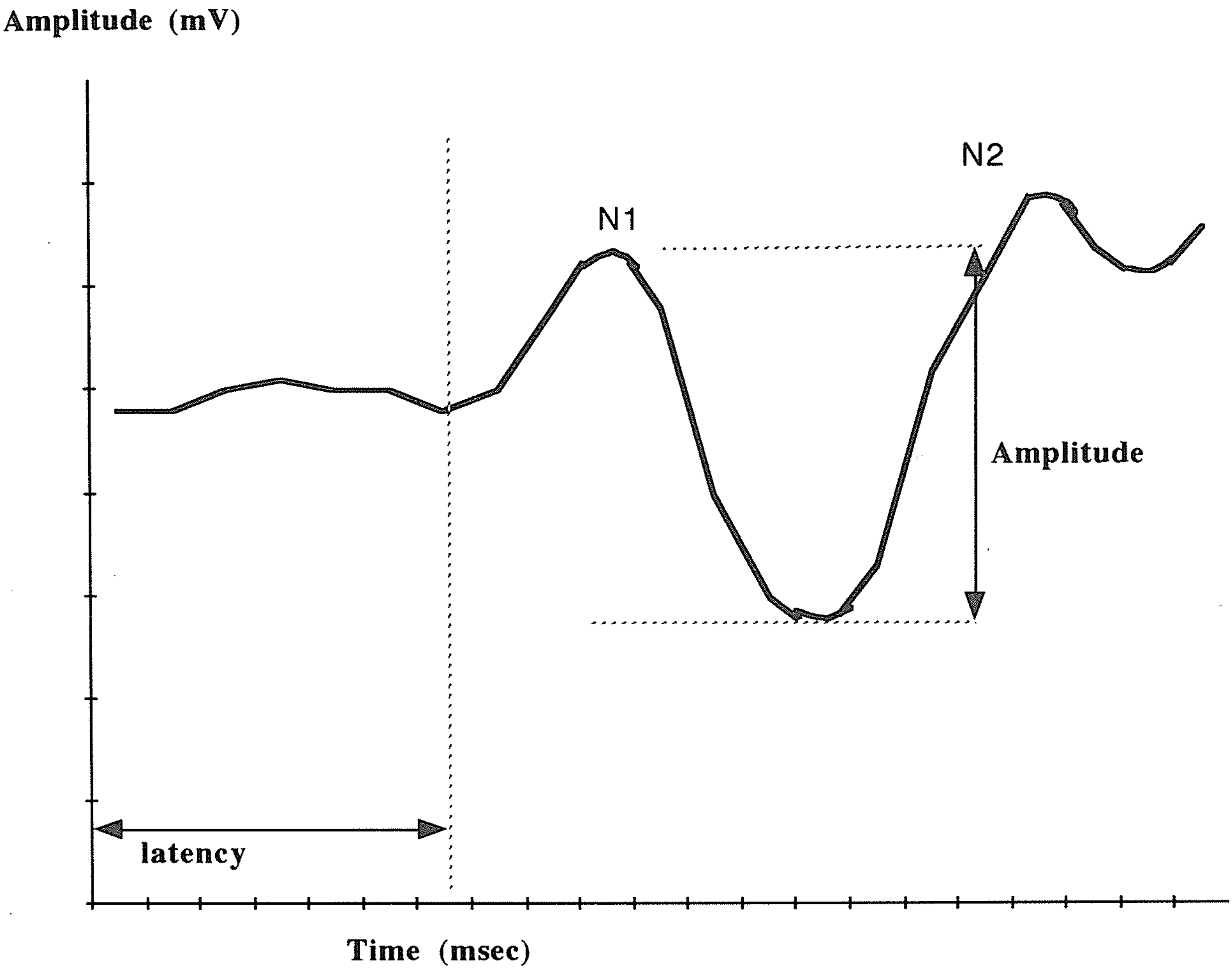

Figure 1. Standart triphasic cortical evoked potential curve: N1 - P1 - N2 curve

According to the amplitude and latency values obtained at the preoperative, postoperative, 1st, 3rd week and 3rd month SEP studies, variance analysis (One way ANOVA - MacStat®) was performed to determine the difference between the groups statistically.

Nothing was done to a dog in the control group. Only the SEP and BCRL monitoring was done during the same days. To make double blind control, other dog was operated. After total two level laminectomy, the electrophysiological studies were done in the same day.

All the dogs were kept alive postoperative 3 months under good conditions. During this time, weekly neurologic examinations were done. Tarlov classification were used in the clinical neurologic examination (9). Grade 1 indicates complete paraplegia, with no motion of the hind extremity; Grade 2, slight motion; Grade 3, the ability to stand; Grade 4, the ability to walk; and Grade 5, the ability to climb a 20° inclined plane.

All of the subjects were sacrificed after the 3 months' period. At the section of stenosis, the cauda equina, dorsal root ganglia, conus medullaris and spinal cord were fixed in 10% formaline and embedded in paraffin. Five micrometer sections were prepared. The sections were stained with hematoxylin eosin and luxol fast blue stains. Then the histopathologic changes were studied.

Table 2. Latency and amplitude changes of SEP and BCRL of the dogs. C Group: Control group. Group 1: The dog with bone block was kept 5 sec. and was removed suddenly after implantation. Group 2: The dog with bone block was implanted 1 minute and was removed after implantation. Group 3: The dog with bone block was implanted during 3 weeks and was removed after 3 weeks. Group 4: The dog with bone block was kept during 3 months. (ms: milliseconds, mV: Millivolt, PR: Preoperative, PO: Postoperative, 1W: 1st week, 3W: 3rd week, 3 MO: 3rd month).

GROUPS	TEST		PR	PO	1W	3W	3MO
C GROUP	SEP	Latency (ms)	19.2±2.8	19.4±2.9	19.8±3.2	19.5±2.6	19.4±2.8
		Amplitude (mV)	1.1±0.2	1.0±0.2	1.0±0.3	1.1±0.4	1.2±0.3
1st GROUP	SEP	Latency (ms)	20.0±3.2	32.2±3.6	28.9±2.7	25.2±2.1	21.0±2.2
		Amplitude (mV)	1.02±0.31	0.78±0.22	0.83±0.28	0.98±0.27	1.01±0.31
	BCRL	Latency (ms)	20.4±3.1	(-)	29.3±3.1	24.4±2.8	20.9±2.6
2nd GROUP	SEP	Latency (ms)	19.3±3.1	39.9±2.8	31.1±3.3	24.4±2.9	22.9±2.6
		Amplitude (mV)	1.02±0.26	0.56±0.19	0.66±0.21	0.73±0.23	0.88±0.38
	BCRL	Latency (ms)	20.5±3.2	38.1±2.9	38.0±3.1	30.4±3.1	24.6±2.7
3rd GROUP	SEP	Latency (ms)	20.0±3.4	39.6±5.7	38.4±4.8	31.9±3.6	29.4±3.1
		Amplitude (mV)	1.02±0.2	0.52±0.41	0.56±0.36	0.65±0.44	0.71±0.51
	BCRL	Latency (ms)	20.5±7.1	38.1±8.1	45.7±9.1	41.1±6.1	32.3±2.8
4th GROUP	SEP	Latency (ms)	20.1±4.7	40.4±5.5	41.4±7.1	42.2±8.1	42.2±6.7
		Amplitude (mV)	1.01±0.2	0.58±0.22	0.54±0.31	0.44±0.22	0.41±0.61
	BCRL	Latency (ms)	20.5±4.6	38.8±8.0	45.7±8.8	52.3±6.9	54.4±8.9
TOTAL (Mean)	SEP	Latency (ms)	19.7±3.1	34.3±6.3	31.9±6.9	28.6±9.4	26.9±9.6
		Amplitude (mV)	1.03±0.2	0.69±0.26	0.72±0.44	0.78±0.51	0.84±0.53

RESULTS

– **Control Group:** The two dogs in the control group had no abnormalities upon neurologic examination at any time. The SEP and BCRL were unchanged from preoperative values (Table 2). The BCRL in the control group ranged from 17-24 msn. Other than mild epidural fibrosis at the laminectomy site, the dogs had no histological changes in the cauda equina.

– **1st Dog (The subject with the osseous block kept for 5 seconds):** In this dog, slight muscle weakness has developed (Tarlov grade 3). Stood up on the postoperative 5th day, began to walk after a week and in the 3rd month became Tarlov Grade 5. The latency and amplitude values of SEP and BCRL monitoring of this dog are seen on Table 2 (Figure 2). In thi histological examination at the end of the 3rd month, no important difference except slight fibrosis were found according to the control group.

– **2nd Dog (The subject with osseous block removed after one minute from implantation):** Middle degree muscle weakness (Tarlov Grade 2) appeared. After three weeks postoperatively it stood up. However it climbed the 20° inclined platform hardly. The results of SEP and BCRL are shown in Table 2 (Figure 3). At the end of the three months, minor degenerative and fibrotic changes were observed between alive and normal tissue histologically.

– **3rd Dog (The subject with osseous block removed after three weeks after implantation):** The dog had a middle degree postoperative muscle weakness (Tarlov grade 2). It could not stand up during three weeks' postoperative time. On the 3rd month, it stood up but hardly moved. The results of SEP and BCRL values were shown in Table 2 (Figure 4). At the end of the third month, a middle degree damage was seen in the peripheral nerves in pathologic sections. Normal, and distrophic axon conditions were observed. There was mild atrophy and degeneration at conus medullaris.

– **4th Dog (The subject with osseous block kept for three months after implantation):** The postoperative neurologic examination findings of this dog

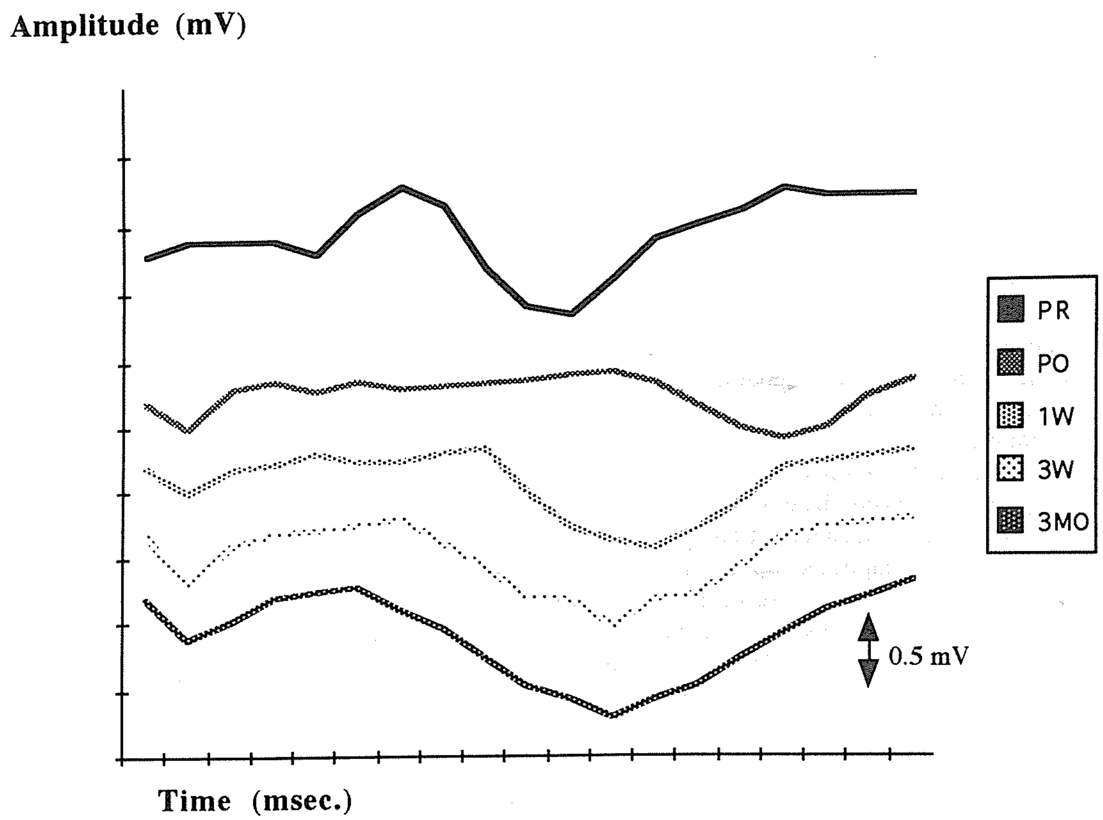

Figure 2. SEP records of the dog with bone block was implanted for 1 minute and was removed after implantation. (PR: preoperative, PO: postoperative, 1W: 1st week, 3W: 3rd week, 3MO: 3rd month.)

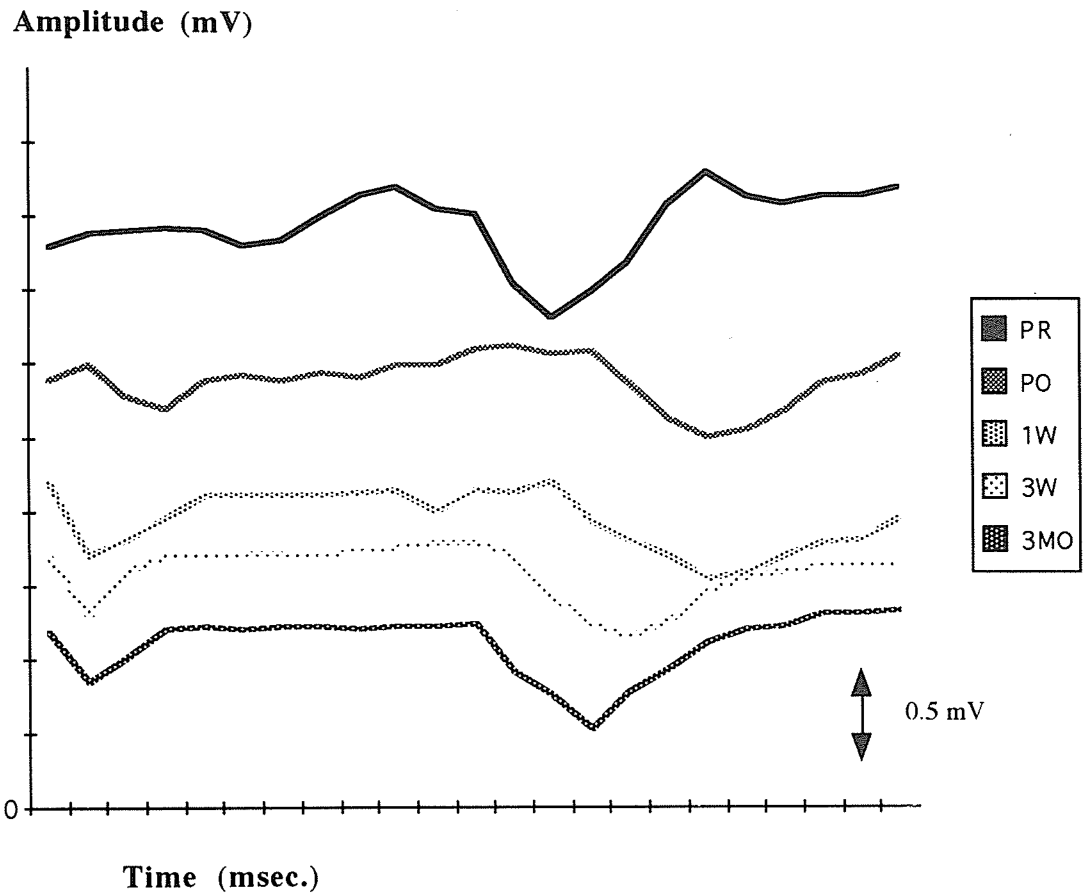

Figure 3. SEP records of the dog with bone block was implanted during 3 weeks and was removed after 3 weeks. (PR: preoperative, PO: postoperative, 1W: 1st week, 3W: 3rd week, 3MO: 3rd month.)

were the same as the third dog. However, it still could not stand up at the end of the third month, postoperatively. The values of SEP and BCRL were shown in Table 2 (Figure 4). Postoperative histologic observation on the 3rd month showed partial atrophy, partly wallerian degeneration, vacuolization at conus and atrophy. There was significant epidural fibrosis.

Average latency and amplitude values of experimental groups are seen in Table 2. According to this table, preoperative latency which was 19.7 msn. came to 34.3 msn, 31.9 msn., 28.6 msn., 26.9 msn. at the postoperative 1st week, 3rd week, 3rd month evaluation. Also amplitude value which was 1.03 mV was found to be 0.69 mV., 0.72 mV., 0.78 mV., 0.84 mV. at the postoperative 1st week, 3rd week, 3rd month control. Difference between the groups were statistically significant according to variance analysis ($p < 0.05$). Latency values were increased and amplitude values were decreased postoperatively in the two groups in which bone block was placed in the spinal canal for five second and 1 minute, but these values came to normal in a short period and continued as normal through 3rd month. Latency was increased for a period in the sample in which bone block was placed for 3 weeks, decreased after 3 weeks and remained slightly increased. Amplitude was significantly decreased postoperatively but increased after 3 weeks. Postoperatively, latency was increased in the sample in which had bone block placed in the spinal canal for 3 months and this increase persisted. Decrease in amplitude continued in the postoperative follow-up period.

DISCUSSION

The signs and symptoms of chronic compression of the cauda equina were suggested to be related to

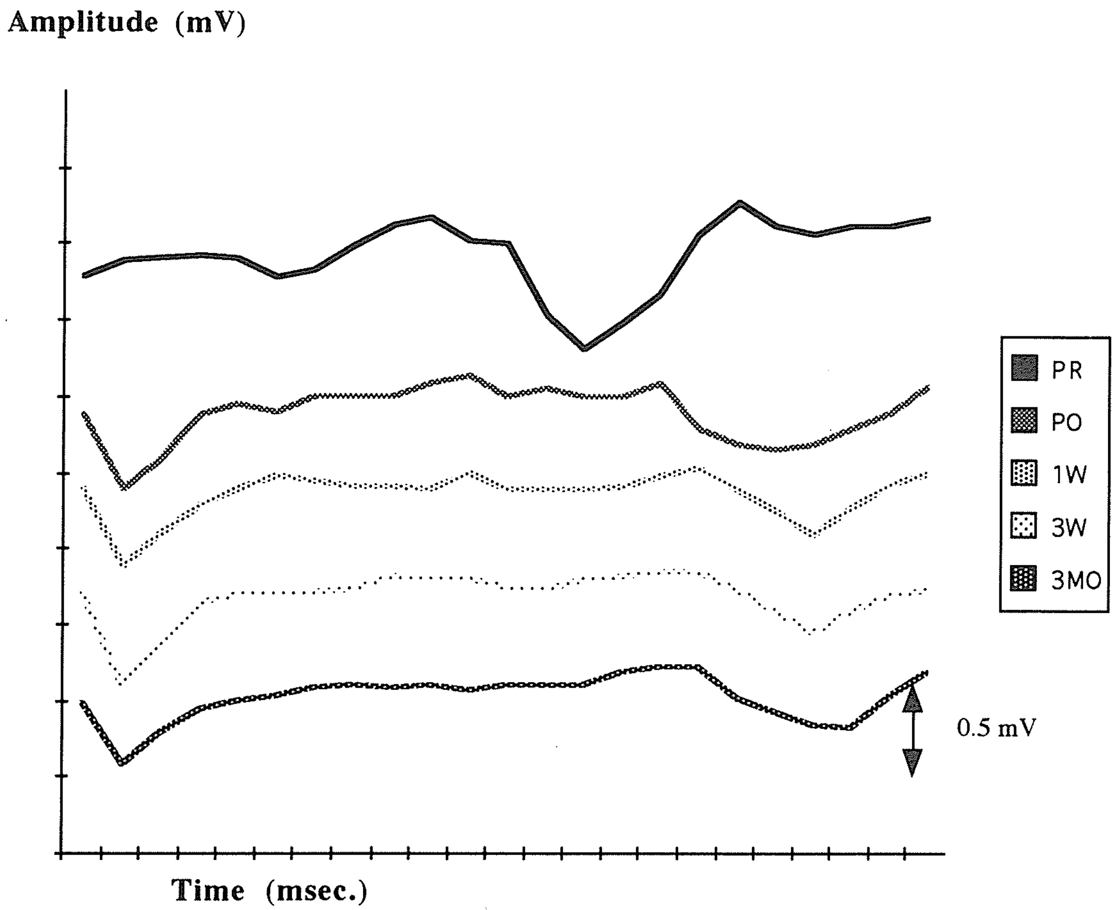

Figure 4. SEP records of the dog with bone block was kept during 3 months. (PR: preoperative, PO: postoperative, 1W: 1st week, 3W: 3rd week, 3MO: 3rd month.)

changes in the intrinsic blood supply, changes in axoplasmic flow and direct neural compression. However, electrophysiologic, pathologic and neurologic changes attendant on the grade of lumbar spinal stenosis were not yet known (4).

According to some authors, changes in blood circulation is the cause of the disease, and some of them suggest that narrowing of the canal plays the main role (3). In their study, Kim et al. showed that 50% of narrowing was the limit value and above this limit neurophysiological and histopathological changes were irreversible (4). In our study, experimental spinal stenosis and its electrophysiological and histological effects were observed in dogs. In the light of datas from study of Kim et al, a new model providing mean narrowing of 51.1% of spinal canal with a variable period of spinal stenosis was created. Our study differ from Kim et al.'s study mainly with its aim to evaluate electrophysiologic, clinic and histologic changes in spinal stenosis of different duration and correlating these changes with respect to this stenosis time.

Spinal stenosis, achieved for 5 seconds in the first dog and for a minute in the second one, caused a Tarlov grade 3 and grade 2 neurologic deficits respectively. Both of the dogs were able to walk after 3 weeks and they were nearly normal in the end of 3 months. The first dog was considered as a model for patients who had cauda damage during instrumentation intraoperatively. The second was considered as a model for spinal trauma or transient cauda damage.

In the SEP monitorization of the first dog, latency had increased from 20.0 ms to 32.2 ms, and amplitude was decreased to 0.78 mV. Latency and amplitude values turned to normal in the third month. The changes of BCRL were similar with respect to time, too. Histopathologically there were no findings except slight fibrosis. In the dog with the osseous block kept for one minute, the latency increased to 39.9 ms and amplitude decreased to 0.56 mV. After 3rd month the latency was turned to nearly normal values with a delay of 3.6 ms. Histologically no important differences were found except for more fibrosis compared to the first dog. According to these findings, at situations like iatrogenic sudden canal narrowing to implant material, as an example of reversible very short acting narrowing of the spinal canal in which pressure is thought to be releived immediately; electrophysiological findings will improve in correlation with clinical improvement and there will not be any important pathological changes except slight fibrosis.

To observe the chronic spinal stenosis, osseous block was used to narrow the canal 50% in two dogs for 3 weeks and for 3 months' time. Clinically Tarlov Grade 2 neurologic deficit turned to Grade 4 at the end of the 3rd month in the dog which the osseous block was kept for 3 weeks. Correlated with that, the latency which had increased to 39.6 ms and the amplitude decreased to 0.52 mV postoperatively; satisfiying improvement in electrophysiologic findings with a delay of 9.4 ms in latency was achived at the end of 3rd month. Histopathologically there was no important detoriation. The fourth dog, Tarlov Grade 2 clinically, showed no improvement. Latency is prolonged to 40.4 ms postoperatively and the amplitude decreased to 0.58 mV. BCRL value become worse till 3rd month and prolonged from 20.5 ms to 54.4 ms. This dog had axonal degeneration, vacuolization and severe degenerative changes histologically. Although there was not enough subjects we thought that 3 weeks time may be critical. In other words decompression which is made in 3 weeks may result in electrophysiologic and histopathologic improvement but in a 3 month period irreversible changes may develop.

The SEP test is one of the electrodiagnostic methods which has been used for the last 30 years primarily for measuring spinal cord damage and for monitoring and determining prognosis (4). Based on experiments on mice, Donaghy and Numato emphasized the prognostic importance of SEP in acute cord damage, saying that the recovery of motor skills related to the early recovery of SEP, and that prognosis is good when SEP recovers within 4 hours, but bad otherwise (2). In 1972, Perot was the first to apply SEP clinically for forecasting and monitoring impending injury during a scoliosis operation (7). Duonch et al diagnosed disc herniation or spinal stenosis using dermatomal SEP and reported 86% accuracy, 89% sensitivity, 81% specifity (2). Kothbauer et al postulated that by intraoperative motor and sensory monitoring, cauda equina functions can be evaluated and anatomic difference between fibrous or neoplastic masses can be done fastly (5). York et al insisted that an exact evaluation should be made covering the whole spinal cauda equina, by performing the motor evoked potential (MEP) test more accurately (10). Owen et al. showed that the MEP test should be done with the SEP to verify whether or not the spinal cord is damaged during spinal surgery (6). BCRL is an important neurological test of urinary difficulty. BCRL is maintained it is delayed or missing when there are pathological changes in micturation center, cauda equina syndrome or peripheral nerve difficulty (4).

We found that results of SEP and BCRL studies were correlated with the clinical and histopatologic findings. In this study the duration of spinal stenosis was found to be correlated with histopathologic and clinical change. In the evaluation of the determination of these changes SEP and BCRL studies were effective methods. Though the number of animals in the study is small, there seems to be a critical period of 3 weeks in which histopathologic and clinical changes are irreversible in dogs. There may be such a critical period also for the patients with spinal stenosis, but determination of this critical period in humans is not possible depending on data and results of this study. However, we concluded that electropyhsiologic evaluation pre and intraoperatively in patients with spinal stenosis may help the clinician and surgeon to determine treatment plan.

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