



# Do intra-operative neurophysiological changes predict functional outcome following decompressive surgery for lumbar spinal stenosis? A prospective study

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**Background:** To analyse the relation between immediate intraoperative neurophysiological changes during decompression and clinical outcome in a series of patients with lumbar spinal stenosis (LSS) undergoing surgery.

**Methods:** Twenty-four patients with neurogenic intermittent claudication (NIC) due to LSS undergoing decompressive surgery were prospectively studied. Intra operative trans-cranial motor evoked potentials (tcMEPs) were recorded before and immediately after surgical decompression. Lower limb normalised tcMEP improvement was used as primary neurophysiological outcome. Clinical outcome was assessed using the Zurich Claudication Questionnaire (ZCQ) self-assessment score, before surgery (baseline) and at an average of 8 and 29 months post-operatively.

**Results:** We found a moderate positive correlation between tcMEP changes and ZCQ at early follow-up ( $R=0.36$ ). At late follow-up no correlation was found between intra-operative tcMEP and ZCQ changes. Dichotomizing the data showed a statistically significant relationship between tcMEP improvement and better functional outcome at early follow-up ( $P=0.013$ ) but not at later follow-up ( $P=1$ ).

**Conclusions:** Our findings suggest that intra-operative neurophysiological improvement during decompressive surgery may predict a better clinical outcome at early follow-up although this is not applicable to late follow-up possibly due to the observed erosion of functional improvement with time.

**Keywords:** Lumbar spinal stenosis (LSS); decompression surgery; intra-operative neurophysiological monitoring; clinical outcome

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## Introduction

Symptomatic lumbar spinal stenosis (LSS) with neurogenic intermittent claudication (NIC) can be treated either conservatively or surgically in particular if symptoms persist and are significantly impairing function (1,2). Decompressive surgery is regarded as the standard surgical approach for symptomatic LSS who have failed conservative treatment. Even though this is a relatively safe procedure neurologically, complications following this type of surgery have been described (3,4) in particular as this population is quite old and likely have multiple co-morbidities. The role of intraoperative neurophysiological monitoring (IONM) in spinal surgery is not completely established and remains controversial (5) but is increasingly used in particular in deformity surgery (6-9). Neurophysiological changes have been documented during lumbar decompression (10,11) and its value in detecting neurological damage with a high sensitivity and specificity have been documented (12). The relation of neurophysiological changes during lumbar decompression and postoperative functional outcome is not well established.

To the authors' knowledge neurophysiological improvement and its relation to early and long-term post-operative clinical outcome have been incompletely studied and the authors believe this is the first study to address this clinical question.

Therefore, our aim was to study the relation between immediate intraoperative neurophysiological changes after surgical decompression and functional clinical outcome using the Zurich Claudication Questionnaire (ZCQ) self-assessment score in a series of patients with LSS undergoing surgery.

## Methods

Human research ethics approval was obtained. We prospectively collected clinical data from a cohort of 24 consecutive patients undergoing decompression during a 28 months period (between October 2010 and February 2012) at a single institution and by a single surgeon.

Preoperatively all patients underwent magnetic resonance imaging (MRI) examinations of their lumbar spine pre-operatively as part of the standard work up protocol. All patients had central stenosis with or without lateral recess stenosis. No patient with cord compression was included even though four cases presented with L1-2 involvement but at cauda equina level. All patients

had failed conservative treatment before consenting for surgery.

### *Anesthetic technique*

Anesthetic induction and maintenance of anesthesia was performed by a total intravenous anesthesia using Sufentanil and Propofol (13,14). Only non-depolarizing muscle relaxants were applied for intubation. Volatile anesthetics were not used during the procedure. Wake up tests were not performed.

### *Surgical technique*

The patients were positioned prone on a Montreal mattress. Patients underwent posterior lumbar decompression of all levels that showed morphological evidence of stenosis on preoperative MRI (grades C&D) (15).

After exposing the posterior elements, our standard surgical procedure consists in distracting the concerned levels by an interlaminar spreader introduced between the spinous processes. This step allows better approach to the interlaminar space, especially if osteophytes are occulting the ligamentum flavum. To complete the decompression medial facet osteophytes were removed with a high-speed burr, followed by the excision of the ligamentum flavum associated to a bilateral laminotomies until the dural sac and nerve roots were completely identified and freed.

### *IONM technique*

Intraoperative trans-cranial motor evoked potentials (tcMEPs) were measured prior to decompression (baseline) in prone position. Depending on the treated level the tcMEPs were acquired from two to four lower limb muscles (bilateral tibialis anterior/abductor hallucis muscles). The reference control value was the response of one upper limb muscle (1st interosseous muscle of the hand). Using two corkscrew electrodes, localized at C1 C2, a transcranial electrical stimulation was triggered at the standard derivations by a 500 Hz train of 5 to 7 1-ms biphasic impulses. Stimulation between 50 to 150 volts was adequate to provoke a consistent motor response. The main outcome measure of tcMEP recording was the relative change of the area under the curve (AUC) of the normalized (to the hand interosseous response) motor response as previously described (16) before and immediately after full decompression. The last measurement coincided with

the end of the surgical procedure, shortly before closure. A 20% improvement has been selected as significant for the purpose of this study (17). This neurophysiological outcome measure was subsequently related to the ZCQ scores (at baseline, early and late follow up time points as described below). Free running electromyography (EMG) analysis was not performed routinely in our study although it has been used in some cases on demand but without prospectively recording results since this was outside our study protocol. In addition, even though we routinely monitored somatosensory evoked potentials (SSEPs) (through the posterior tibial nerve) we did not use that data since it concerned mainly one nerve root (S1).

### Follow-up

Postoperatively patients were followed by at regular intervals by the surgical team. Latest self-assessment questionnaire was obtained either during that last visit or by postal correspondence.

Complete early and late follow up data was available in 18 of those cases at an average of 8 months (early follow-up) and at 29 months (long term follow-up).

### Functional evaluation

The ZCQ self-assessment score served as primary functional outcome measure. It consists in a three item score measuring symptom severity and physical function, as well as patient's satisfaction following surgery. The 0.5 scale points change (i.e., relative change divided by baseline must be at least greater than 0.5) has been considered as significant for this study as previously reported (18,19). Patients completed the ZCQ before surgery (baseline), at an average of 8 (range, 3–12) and of 29 (range, 21–37) months following surgery (short and long term outcome, respectively).

### Statistical analysis

Fisher's exact test and the Linear Pearson Correlation test were used as appropriate. Little number of patients made dichotomizing of data necessary.

## Results

There were 24 patients included in the prospective study with mean age of 69 years (range, 51–84 years). Male:female

ratio was 0.8 in this cohort. Eighteen patients had long-term follow-up. Ten patients had single level involvement and eight had multilevel surgery (*Table 1*). There were no neurological injuries following surgery.

The average baseline ZCQ score was 72% (range, 47–85%). At early follow-up an average score of 46% (range, 24–78%) was achieved with an average change of 26% (range, 3–54%). There was no significant association between change in ZCQ score at early follow-up with gender ( $P=0.389$ ) or age of the patient ( $P=0.627$ ). At late follow-up the average ZCQ-score was of 57% (range, 27–90%) with an average absolute change from baseline of 15.5 (range, 14–40). There was no significant association between change in ZCQ score at late follow-up with gender ( $P=0.478$ ) or age of the patient ( $P=0.834$ ). There was no correlation between any of the demographic variables and improvement in ZCQ.

At early follow-up all patients showed improvement in the absolute result of ZCQ. From those, seven did so in a significant way (relative point scale score  $>0.5$ ). At latest follow-up, only four patients had still a significant improvement of their ZCQ score compared to the baseline outcome (relative point scale score  $>0.5$ ).

Eight patients showed an intra-operative improvement of their tcMEP in excess of 20%, while three improved less than 20%. Seven patients did not show any tcMEP improvement at all at the end of the decompression.

We found a moderate positive correlation ( $R=0.38$ ), between tcMEP changes and ZCQ relative point score at early follow-up (*Figure 1*).

At latest follow-up nevertheless only a very fair correlation ( $R=0.11$ ) was found between tcMEP and ZCQ changes (*Figure 2*).

Dichotomizing the data using a 50% improvement for ZCQ and 20% for tcMEPs as cut-off points showed a statistically significant relation between tcMEP improvement and better functional outcome at early follow-up ( $P=0.013$ ) (*Table 2*) disappearing at 24 months ( $P=1$ ) (*Table 3*).

## Discussion

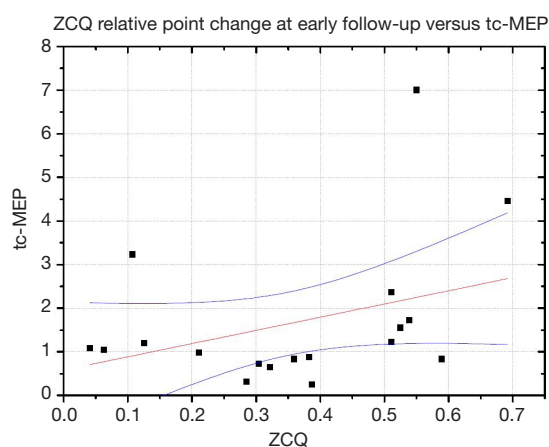
In this study we found that tcMEP improvement was related to a better functional outcome but only in the early follow-up. This improvement was found to be between equivalent amongst males *vs.* females and similar across the age range studied.

The constantly increasing number of surgical procedures

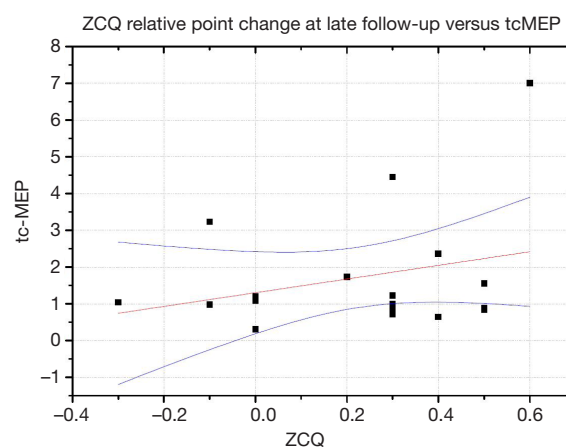
**Table 1** Detailed data on operated levels and outcome measures

Case number	Gender	Age	Operated levels	Baseline ZCQ score	Early ZCQ score	Late ZCQ score	Early ZCQ relative change scale	Late ZCQ relative change scale	Normalized tcMEP change
1	M	84	L12	37	38	52	0.285	-0.045	0.310
2	F	79	L12, 45	26	35	48	0.063	-0.285	1.040
3	F	56	L34	40	35	41	0.391	0.286	1.000
4	F	67	L34	43	19	46	0.692	0.255	4.450
5	M	51	L23, 34, 45	45	51	71	0.211	-0.098	0.977
6	F	71	L23, 34	43	54	63	0.126	-0.020	1.200
7	F	81	L34	34	22	26	0.525	0.468	1.550
8	M	57	L34	34	22	21	0.550	0.570	7.000
9	F	82	L23, 34	47	33	50	0.511	0.259	1.225
10	M	64	L34	44	26	34	0.589	0.462	0.830
11	M	60	L34	44	39	32	0.383	0.494	0.880
12	F	81	L45, L5S1	35	14	31	0.511	0.383	2.360
13	M	58	L12, 23, 34, 45	46	59	70	0.107	-0.059	3.230
14	F	80	L23	39	38	36	0.322	0.357	0.640
15	F	64	L34, 45	38	35	40	0.359	0.267	0.830
16	M	51	L12, 23, 34, 45	35	22	39	0.539	0.224	1.728
17	M	80	L45	45	62	65	0.041	-0.006	1.080
18	F	79	L45	41	41	40	0.304	0.321	0.720

ZCQ score, maximum achievable points at baseline are 55 and after surgery 79 (the lower the score, the better the result); ZCQ relative change scale, relative change divided by baseline score (values over 0.5 are considered significant); normalized tcMEP change, improvement if value  $\geq 1.2$ . ZCQ, Zurich Claudication Questionnaire; tcMEP, trans-cranial motor evoked potential; M, male; F, female.



**Figure 1** ZCQ relative point change at early follow-up versus tcMEP. Black squares correspond to individual patients. ZCQ, Zurich Claudication Questionnaire; tcMEP, trans-cranial motor evoked potential.



**Figure 2** ZCQ relative point change at late follow-up versus tcMEP. Black squares correspond to individual patients. ZCQ, Zurich Claudication Questionnaire; tcMEP, trans-cranial motor evoked potential.

**Table 2** The early follow-up Fisher’s exact test: this result is significant with P=0.013

ZCQ score	tcMEP better	tcMEP unchanged	Total
ZCQ improved	6	1	7
ZCQ unchanged	2	9	11
Total	8	10	18

ZCQ, Zurich Claudication Questionnaire; tcMEP, trans-cranial motor evoked potential.

**Table 3** The late follow-up Fisher’s exact test: the P value is 1

ZCQ score	tcMEP better	tcMEP unchanged	Total
ZCQ improved	2	2	4
ZCQ unchanged	6	8	14
Total	8	10	18

ZCQ, Zurich Claudication Questionnaire; tcMEP, trans-cranial motor evoked potential.

demands thorough vigilance towards integrity of neural structures (20). In order to receive real-time feedback, neurophysiological assessments during surgery were introduced and have developed into a useful tool (7,10,21) IONM has clearly been shown to be effective in spinal cord tumours (22). Its use is nevertheless not widely accepted. Sharan *et al.* couldn’t find any evidence in the literature that IONM can help in preventing nerve root injuries in the context of pedicle instrumentation (23). Similarly, not all neurological incidents had been recognized by IONM in a study by Alemo *et al.* (5). There is not always a distinction in literature reviews between the different modalities in particular between SSEPs and motor evoked potentials (MEPs) which differ in their prognostic value with SSEPs being regarded as less sensitive (24).

Little is known so far about the possible positive effect of surgical decompression procedures to the electrophysiological response and functional outcome.

Most recently the IONM, more precisely the evoked potentials (EPs) in general, are gaining importance as so called, biomarkers (25).

The full validation of IONM is in process and controlled trials are required to confirm its role; a very difficult task, because patients will not except to relinquish the potential benefit of this tool (25).

Studying the specificity and sensitivity of IONM is beyond the scope of our research. We aimed to identify

any relation between intraoperative tcMEP changes and functional outcome, something that has to our knowledge been studied only incompletely.

Indeed Voulgaris *et al.* compared the IONM responses to the visual analog scale (VAS) score at 12 months postoperatively and found a greater improvement in the VAS score for patients demonstrating significant tcMEP improvement (26). VAS score is nevertheless not disease specific and ZCQ had not been studied.

Our study is therefore the first one to compare the IONM with a disease specific functional outcome score. The present study shows that immediate neurophysiological response in IONM after decompressive surgery for LSS is correlated with a positive effect on the clinical outcome after an average of 8 months of follow up. At late follow-up of more than 28 months after surgery the beneficial effect of decompression surgery declines gently and no significant correlation could be found between the tcMEPs response improvement and ZCQ score. The outcome worsening at long term is commonly observed in other studies on surgical outcomes following decompression (27).

The present study is limited by several constraints. Our study is a small case series, but it does give a neurophysiological account of the immediate changes observed during decompressive surgery. We did observe though that the lack of tcMEP improvement was somehow in relation to a lesser functional improvement whatever the origin of this poor tcMEP response might have been. Since we used only intra-operative tcMEPs to compare with functional scores, we were not able to describe the neurophysiological response at late follow-up. Future research should focus on late neurophysiological changes in a larger cohort of patients. In addition the clinical outcome score is a self administered questionnaire and not an objective measure although this type of subjective outcome is widely used in spinal surgery.

Our findings suggest that intra-operative neurophysiological improvement during decompressive surgery may predict clinical outcome at 6 months following surgery. Nevertheless, as it has been observed with other spinal procedures, the initial improvement in functional outcome diminishes with the passage of time making the relation between function and neurophysiological changes less meaningful. Initial neurophysiological changes could be useful in predicting short-term failures. The small number of cases presented in this paper makes it mandatory to apply caution in the interpretation of our results. Further research with a greater number of cases and a more homogeneous



population would be necessary before drawing definitive conclusions.

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## Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

*Ethical Statement:* This study was approved by the local ethical committee—Commission d’Ethique (Bugnon 21, 1005 Lausanne, Switzerland).

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