The value of neurophysiological and imaging studies in predicting outcome in the surgical treatment of cervical radiculopathy

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Abstract It is not always easy to predict the degree of symptomatic improvement to be expected in a patient undergoing surgery for cervical disc herniation and radiculopathy. Here we investigate whether preoperative electromyography (EMG) can help select those most likely to benefit from intervention. We prospectively evaluated 20 patients whose required operative level was unclear after clinical examination and MRI scan alone. The surgical procedures was anterior cervical interbody fusion with the AcroMed[®] carbon fibre cage. Clinical assessment employed using validated scoring systems (Prolo functional and economic scoring system). Patients underwent MRI preoperatively, and were assessed pre and postoperatively with neurophysiological studies (NPS) including nerve conduction studies and concentric needle EMG. Patients with preoperative evidence of cervical nerve root involvement on EMG (group A, $n = 8$) had better outcome ($P = 0.001$) following discectomy and anterior fusion than patients who had no evidence of nerve root damage on EMG (group B, $n = 12$). Prolo mean score $\pm$ SEM for group A was 7.375 ± 0.3750 and for

group B was 5.583 ± 0.2876 . Thus, NPS are a valuable tool in selecting patients in this subgroup for cervical surgery.

Keywords Cervical radiculopathy · Neurophysiological studies · AcroMed[®] fusion cage · Outcome

Introduction

The outcome of the operative treatment of cervical disc herniation with radiculopathy is often unpredictable, despite the development of a range of surgical procedures. The main problem remains the selection of patients suitable for the procedure. There is no clear method available to evaluate patients before surgery and there appears to be little agreement on the selection criteria for surgical treatment. Good to excellent surgical results in past studies range widely from 66 to 98% of patients [3, 5, 7, 12, 22, 23, 24, 29].

The true diagnostic accuracy of clinical examination for cervical radiculopathy is debatable. Sensory deficit, deep tendon reflexes and motor weakness may be present to a varying degree. Loss of deep tendon reflexes is usually said to be the most reliable clinical finding, with the biceps reflex affected by C5 injury, the brachioradialis by C6, and the triceps by C7 [10]. The correlation though between MRI and surgical findings is frequently unreliable as the evaluation of false positive and false negative findings can be influenced by the experience of both the radiologist and the surgeon [25].

It appears that there are no clear standard clinical or investigation criteria for the diagnosis and most

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importantly, selection of patients with cervical radiculopathy for surgery. It is important that we can identify the subgroup most likely to benefit from surgery in order to choose whom to operate upon, and to give a reasonable estimate of prognosis to our patients. This study investigates whether electromyography (EMG) studies can be used to identify the subgroup with better postoperative outcome.

Materials and methods

Patients undergoing anterior cervical interbody fusion, using the AcroMed® carbon fibre cage for cervical radiculopathy in our unit were prospectively assessed for eligibility into this study. In our unit only those patients where the operative level was unclear after clinical and MRI assessment underwent neurophysiological studies (NPS). Patients with cervical myelopathy, past cervical surgery for radiculopathy, inability to undergo NPS, or a history of mental illness, drug or substance misuse, diabetes were excluded from the trial. Twenty patients were included in the study, 12 women and 8 men. The mean age ($\pm$ SD) was 49 ± 10 years and the median was 50 years. The patients were divided into two groups (A and B) based on preoperative NPS findings. Patients were classified according to preoperative neurophysiological findings (normal or abnormal). The relevant ethical committee approved the study, and all patients gave their informed consent.

The preoperative diagnosis was based on the presence of symptoms and signs of cervical root involvement. These included pain in the neck and shoulder which radiated down to the arm; stiffness in the neck and shoulder, weakness and muscle atrophy in myotomal distribution, dermatomal sensory impairment and depressed or absent reflexes.

Preoperative radiological assessment involved flexion and extension lateral radiographs and MRI of the cervical spine. Standardized electrophysiological examination was undertaken prior to surgery, and at least one year postoperatively. This comprised nerve conduction studies (NCS) and concentric needle EMG using a computerised EMG machine (Nicolet Biomedical-Viking IVP®). Evidence of denervation changes on needle EMG included the presence of spontaneous activities (fibrillations, positive sharp waves and fasciculations) and long duration polyphasic motor units.

Patient outcome was also measured at least one year after surgery using a modified version of the Prolo functional and economic scoring system. This is a

standardized and validated outcome measure, which was originally designed for lumbar spine symptoms. Davis et al. [6] have modified this for postoperative use as the modified Prolo functional and economic scoring system. This system assesses any change in symptoms severity, functional ability, and quality of life. The modified Prolo total score represents the sum of functional and economic scores. A poor outcome is indicated by a score of 4 or less, a moderate outcome by a score of 5 or 6, a good outcome by a score of 7 or 8, and an excellent outcome by a score of 9 or 10 [21]. Patient's satisfaction and opinion was also assessed using other validated instruments, which included eight items of patient's satisfaction scale and four separate items regarding patient's opinion [2]. The eight items of patient's satisfaction scale has five response options for each item (completely satisfied, very satisfied, somewhat satisfied, dissatisfied, and very dissatisfied). Satisfaction with the results of surgery was regarded as relief of symptoms, dysfunction and improvement in the ability to perform work or tasks of daily living. Scale scores were calculated as the mean score of the answered items on each scale. The first of the four separate items concerning patient's opinion refers to satisfaction with the overall results of surgery, with five response options equal to those on the satisfaction scale. The second item refers to the effect of surgery on quality of life with five response options (much improved, slightly improved, unchanged, slightly worse, much worse). The third and fourth items refer to willingness to have the same operation if able to make the decision again and willingness to recommend the surgery to a close friend, with both items having five response options (definitely, probably, unsure, probably not, definitely not).

Results

Group A patients ($n = 8$) showed positive evidence of radiculopathy on NPS and group B patients ($n = 12$) showed no evidence of radiculopathy on NPS. All patients had anterior cervical interbody fusion using AcroMed® cage and autologous iliac bone graft. Diagnosis of cervical radiculopathy was based on the presence of radicular pattern of pain and sensory deficit or motor weakness or both. The most frequent presenting symptoms noted were neck and shoulder pain radiated to one arm in all patients (100%), followed by stiffness in the neck and shoulder, weakness and paresthesia in a dermatomal distribution. The level of most frequently involved root was C6 followed by C7 and C5. All patients had evidence of cervical

degenerative disease on plain radiography and magnetic resonance imaging. Neurophysiological studies were performed to support the diagnosis and to exclude other associated peripheral nerve lesions.

Statistical analysis was performed using the SPSS mathematical program (SPSS, V.9, Inc., Chicago, IL)[®], and the (Graph Pad Prism 3.0)[®]. The data for the two groups was defined and compared using mean $\pm$ SD, mean $\pm$ SEM, and unpaired Student *t*-test. Results were accepted as significant when $P < 0.05$.

There was no statistically significant difference in age between the two groups mean $\pm$ SD was (49.9 ± 7.5 and 49.7 ± 12.2). The most common surgically fused level was C5/6 in 16 patients, followed by C6/7 in seven patients and C4/5 in two patients. Fifteen patients had one level fusion and five patients had two level fusions.

Preoperative NPS (EMG and NCS) in group A showed evidence of denervation and re-innervation in the distribution of one or more cervical nerve roots. Magnetic Resonance Imaging of the cervical spine showed disc bulge and narrowing of exit foramina in all patients. The agreement between NPS, MRI and the surgically treated level/s in the total sample was 40% (Table 1).

Sensory nerve conduction study in group A shows associated evidence of median nerve compression at the wrist in two patients (Table 1). In group B, none of the patients had evidence of nerve root compression on preoperative NPS; however, all patients had evidence of disc bulge and narrowing of the exit foramina on MRI scan. Pre and post-operative nerve conduction study in group B shows evidence of median nerve compression at the wrist in two patients and one patient have ulnar nerve lesion at the elbow (Table 2).

Outcome in the entire group was assessed at least 12 months following surgery. The total Prolo mean

score $\pm$ SD was 6.3 ± 1.8 . This represents an overall moderate outcome. These scores reflect outcomes over a mean follow-up period of 28 months (Table 3).

Prolo outcome score was measured and compared between group A with abnormal EMG, and group B with normal studies. Unpaired Student *t*-test demonstrated a significantly better outcome in group A compared to group B ($P = 0.001$). The total Prolo mean score $\pm$ SEM for group A and B was (7.37 ± 0.37), and (5.58 ± 0.29), respectively. Prolo descriptive Statistics for group-A and B respectively are shown in (Table 4).

Also significantly higher postoperative patient satisfaction scale have been noted in group A compared to group B ($P = 0.01$). The satisfaction Mean score $\pm$ SEM for group A and B was (2.02 ± 0.35) and (3.34 ± 0.29).

Multivariate Analysis between variables including age, number of level involves (MRI, EMG and surgery), work status before and after surgery (unemployed, office type work and manual), dominant hand, severities of symptoms were all considered. The only significant predictor to outcome was preoperative EMG findings ($P = 0.0001$).

Results of the postoperative NPS (NCS and EMG) for group A found all but one (7 of 8) revealed a pattern of longstanding stable re-innervations changes manifested by the absence of spontaneous activities and the presence of large polyphasic motor units. However, one patient showed active denervation suggesting ongoing compression on the C5 nerve root. No patients in group B had evidence of root compression or irritation on pre or postoperative NPS.

The working status of patients in group A comprised seven patients who were employed before surgery and one unemployed. Five patients were able to go back to their original work with no or slight limitation and one patient had to take an early retirement. He described his activity being restricted due to persistence symptoms of mainly moderate neck pain and stiffness. However, in group B, 10 patients out of 12 were employed; 7 had to take early retirement and described themselves as restricted to disabled.

Table 1 Group-A patient, showing root lesions NPS, MRI, surgically fused levels, associated peripheral neuropathy and Prolo total score

NPS root lesion	MRI root lesion	Surgically fused level/s	Associated peripheral nerve lesion	Prolo total
C5/6/7	C6/7	C5/6 + C6/7		7
C5/6	C5/6 + C6/7	C5/6 + C6/7		8
C5/6	C5/6	C5/6		6
C5/6	C4/5 + C5/6	C4/5 + C5/6		9
C5/6	C5/6 + C6/7	C5/6 + C6/7		6
C6/7	C4/5 + C5/6 + C6/7	C5/6	CTS	8
C5/6	C4/5 + C5/6	C5/6 + C6/7		7
C6	C5/6	C5/6	CTS	8

NPS neurophysiological studies, MRI magnetic resonance imaging, CTS carpal tunnel syndrome

Discussion

Here we discuss one method that may help to identify those patients likely to experience improved postoperative outcome, namely the use of EMG. This is important because many other approaches have been shown to be of only limited assistance. Clinical examination is not always straight forward if the patient is in

Table 2 Group-B patients, showing the MRI and surgically fused levels, associated peripheral neuropathy at the same side and Prolo total score

MRI (root lesion)	Surgically fused level	Associated peripheral nerve lesion	Prolo total
C5/6	C5/6		6
C5/6	C5/6		5
C5/6	C5/6		7
C5/6 + C6/7	C5/6		6
C5/6	C5/6		6
C5/6	C5/6		5
C3/4 + C5/6 + C6/7	C5/6		7
C5/6 + C6/7	C5/6	Carpal tunnel syndrome	6
C4/5	C4/5	Carpal tunnel syndrome	6
C3/4 + C4/5 + C5/6	C6/7	Ulnar tunnel syndrome	4
C5/6 + C6/7	C6/7		4
C5/6 + C6/7	C6/7		5

Table 3 Outcome in the entire group using the Prolo functional and economic scoring system 12 months following surgery

	Total number	Minimum	Maximum	Mean $\pm$ SD
Functional	20	2.00	5.00	3.55 $\pm$ 0.94
Economic	20	2.00	4.00	2.75 $\pm$ 0.63
Prolo total	20	4.00	9.00	6.3 $\pm$ 1.34

SD standard deviation

pain [25]. Plain radiographs in various projections may be helpful, but clinical symptoms often correlate poorly with the radiological findings [13]. Imaging techniques are mainly directed to localize the abnormality, identify compression of the spinal cord, nerve roots, and to exclude intraspinal lesions. Shafaie et al. [25] have reported that correlation between MRI and surgical findings is frequently unreliable. Patients spend much of their time upright with the spine in motion, but the vast majority of MRI scans are still performed lying flat with the spine motionless. Furthermore abnormalities in MRI have been found in asymptomatic subjects. Ten percent of those under the age of 40 years are thought to have disc herniations, while over the age of 40 years

Table 4 Total Prolo results for groups A and B

	Number	Minimum	Maximum	Median	Mean	SD
Prolo group A	8	6.00	9.00	7.50	7.375 *	1.06
Prolo group B	12	4.00	7.00	6.00	5.583*	0.99

* $P = 0.001$

20% have evidence of foraminal stenosis, and 8% have disc protrusion or herniation [4].

Neurophysiological investigations are perceived by many as being helpful in the diagnosis of cervical radiculopathy and are also useful in excluding peripheral nerve lesions. Concentric needle EMG appears to be the best and widely accepted method among all electrodiagnostic procedures for the diagnosis of radiculopathy [8] with sensitivity in cervical radiculopathy varying from 50 to 93%.

Knutsson [15] reported that needle EMG correlates with root injury at surgery in 79% of patients based on the presence of fibrillations and positive sharp waves in limb muscles. Falck et al. [9] reported that a normal EMG finding both at one year and five years following surgical decompression was related to a good outcome. Khan et al. [13] reported normalization of cervical SSEP (somatosensory evoked potential) in patients who had completely recovered after surgery. Ashkan et al. [1] reported that sensitivity of both MRI and NPS for the diagnosis of cervical radiculopathy was 93 and 42% respectively, whilst the positive predictive values for MRI and NPS were similar 91 and 86%. MRI had a higher negative predictive value (25% vs 7%). However, agreement between MRI and EMG was highest in patients with clear radicular symptoms and abnormal clinical signs (60%), suggesting that MRI and EMG remain complementary modalities in the evaluation of cervical radiculopathy [1, 8, 9, 11, 15, 16, 18, 19].

A review of the literature regarding the prognostic value of NPS in radiculopathies appears somewhat conflicting. For example, in several studies pre and postoperative EMG has failed to provide prognostic information in cervical radiculopathy [14, 17, 20, 26, 27, 28]. Toyokura et al. [27] have reported that F-wave has a prognostic value compared with conventional motor nerve conduction studies. Trials comparing neurophysiological findings and outcome after spinal surgery using validated outcome measures are notably scarce. Tullberg et al. [28] based their outcome assessment for lumbar radiculopathy on the visual analogue scale. They reported significantly better surgical outcome ($P < 0.01$) in patients with abnormal electrophysiological studies at one year after surgery compared to those with normal studies.

To date no study has compared surgical outcome using a validated outcome instrument with the neurophysiological and imaging findings, before surgical decompression and fusion for cervical radiculopathy. Several articles have presented apparently successful series of patients with radiculopathy, who undergo anterior cervical discectomy and interbody fusion.

However, few provide thorough assessment scores to demonstrate the severity of the symptoms. In this paper, we have demonstrated that in the entire group of patients with radiculopathy, there was a moderate improvement in outcome after anterior discectomy and fusion at the levels indicated by clinical symptoms and MRI scans. However, a significantly larger improvement was found in those who also had abnormalities in needle EMG examination (group A). The better outcome in these patients suggests that the best candidates for surgery are likely to be those with positive needle EMG examination.

This suggests that one way to improve the likelihood of predicting patients who which benefit from any surgical intervention is to limit surgery to those with abnormal neurophysiological tests. This though is not the sole indication for surgery, but if surgery is to be performed on patients with normal neurophysiological tests, these patients should be counselled preoperatively that any postoperative improvement in symptoms might not be dramatic.

Conclusion

This study has demonstrated that preoperative NPS can help in identifying which patients with cervical radiculopathy are more likely to benefit from surgery. Patients with abnormal needle EMG examination preoperatively are likely to benefit much more from surgical decompression and fusion than those with normal preoperative EMG. EMG, therefore, should always be used in conjunction with MRI scan for the evaluation of patient with cervical radiculopathy, especially if surgery is to be considered.

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