Superiority of motor level over single neurological level in categorizing tetraplegia

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The purpose of this paper is to demonstrate the superiority of the American Spinal Injury Association motor level (ML) and upper extremity motor score (UEMS) to the neurological level (NL) in determining self care function in motor complete tetraplegia. Fifty subjects with traumatic motor complete tetraplegia, NL C4–C8, were evaluated at admission and 12 months post injury. At both time periods NL, ML, and UEMS were determined. At 12 months, reported ability to perform six feeding activities of the Quadriplegia Index of Function (QIF) were documented. Spearman correlations of the NL, BML, WML, UEMS, and feeding QIF scores were conducted, and results were compared with *t* tests for significant differences. Both the best and worst ML were more highly correlated to the UEMS than was the NL (0.96 and 0.96 vs 0.66, $P < 0.001$). The best and worst ML were more highly correlated to the QIF feeding score than was the NL (0.74 and 0.72 vs 0.56, $P < 0.05$). The UEMS had the highest correlation to the QIF feeding score, 0.78. These results suggest that the NL is an imprecise descriptor of the impairment in SCI, and is therefore a poor predictor of the resultant disability. The ML and the UEMS better reflect the severity of impairment and disability after motor complete tetraplegia.

Keywords: tetraplegia; spinal cord injury; motor level; neurological level; disability assessment

Introduction

For over 40 years clinicians and researchers have attempted to correlate the neurological examination of individuals with spinal cord injury (SCI) with expected functional capacity.¹ Function is related to the level and completeness of injury. Completeness of injury has been categorized by the Frankel grades² and more recently by its modification, the American Spinal Injury Association Impairment Scale.³ The 'neurological level' has been a frequently used method for designating the level of injury in SCI for many years.^{4–6} The American Spinal Injury Association (ASIA) defines the neurological level (NL) as 'the most caudal segment of the spinal cord with normal sensory and motor function on both sides of the body'.³ Separate motor and sensory levels can be developed for the left and right sides for each patient. The 1992 ASIA standards recommend that, if motor and sensory levels on a given side differ, the NL should not be used. Instead, when asymmetries exist, it is strongly recommended that separate motor and sensory levels be reported.³

There is no consistent agreement as to how to best classify individuals with SCI when analyzing for functional capacity. Long and Lawton¹ were the first to relate motor power to eventual performance of self

care and mobility tasks. They categorized functional potential based upon functioning muscle groups at specific spinal cord lesion levels. The ASIA standards identify key muscles for cervical levels. The rostral root supplying a given muscle is considered intact if the muscle has at least a grade 3 strength. Welch⁷ used the ASIA standards but defined a functional grade as 3+ rather than 3. Some authors^{8,9} have defined the NL as requiring a grade of 4 or 5 on the manual muscle test (MMT). One author¹⁰ combined levels such as C4–5. Some authors¹¹ do not specify how they defined the level of injury. Additionally, various authors (11–13) have developed similar appearing tables of function based on 'neurological levels' but their descriptions of expected functions differ. For example, the listed feeding capability of a person with C5 tetraplegia varies from dependent to independent.¹⁴ This wide variation is due in part to a lack of precision in previous self care measures and also to a lack of precision in definitions of the NL.

Most studies do not specify whether the motor level (ML) was symmetrical or asymmetrical, or whether the sensory level was the same as the ML. Asymmetries are common in cervical SCI. Waters *et al*¹⁵ found that 56% of individuals with complete tetraplegia have asymmetric motor levels at 1 year. At 1 month, the sensory level and the ML differed in 51% of cases. Without the

specification of these differences, a patient with a left C5 sensory, C6 motor level and a right C6 sensory, C7 motor level would be classified as a C5 NL. This patient, with C7 motor level on one side, could perform many self care activities according to the results of Zafonte *et al*.¹⁶ A different patient, with symmetrical C5 left, right, motor and sensory levels, would also be classified as a C5 NL. However, he/she would be able to perform very few self care activities. The more precise description of ML, rather than NL, should yield a better correlation of impairment with self care function.

No published paper has examined whether motor capacity or single NL is better correlated with self care function. In a presentation at the 1994 International Rehabilitation Medicine Association meeting, Ota *et al*¹⁷ reported a more linear relationship for upper extremity motor score to Functional Independence Measure (FIM) score than for NL to FIM score in motor complete SCI patients. Only 22 of their patients were tetraplegic, and evaluation times ranged from 2 to 328 months post injury. They felt that FIM scores reached a plateau by 12 months.

The Quadriplegia Index of Function (QIF) was developed to detect clinically important changes in function in individuals with tetraplegia that other instruments, such as the Barthel Index, were unable to detect. It was reported to have good inter-tester reliability, and to be more sensitive than the Barthel Index to change during inpatient rehabilitation.¹⁸ Although the QIF is comprised of 10 self care variables, a preliminary investigation at our center revealed that a majority of self care tasks in the QIF could be reduced in number with no loss of essential information regarding patient performance (Segal, unpublished data). Most of the tasks in the feeding category of the QIF could not be reduced, and it was concluded that the feeding tasks were most likely to represent distinct functional abilities in tetraplegics. In addition, a study by Zafonte *et al*¹⁶ indicated that the ability to perform QIF feeding tasks differed by ML in patients with tetraplegia.

The purpose of our study is to compare the ML and the single NL to determine which is better correlated with functional abilities in motor complete cervical SCI subjects. Our hypothesis is that feeding ability as measured by the QIF will be better correlated with the ML than with the NL.

Methods

Motor complete traumatic cervical SCI individuals with NL of C4–8 and Frankel grades of A or B on admission to our facility were included in this study. These subjects were selected from the pool of 412 individuals admitted within 2 weeks after cervical SCI to a regional spinal cord injury center between January 1, 1988 and December 31, 1992. All participants consented to involvement in our research protocols. All were cooperative at the time of examination, were medically stable, and had no upper extremity fractures. A

complete neurological examination was performed on each subject at admission and at 12 months post injury by our trained staff of physicians and research technicians. Fifty subjects fit our inclusion criteria, had the required neurological examinations documented, and had documented appropriate QIF scores, as discussed below. Thirty eight patients with appropriate NL on admission were excluded due to inability to obtain needed data at 12 months post injury.

Using the neurological examination at 12 months post injury, a single NL, ML, and upper extremity motor score (UEMS) were calculated for each subject. The NL, as defined by ASIA at the time of this study, is the lowest (most caudal) neurological segment with normal sensation (all sensory modalities) and a muscle grade of fair (3) or better.¹⁹ The ML is defined by the lowest key muscle with a grade of at least three, if the key muscles above that level are normal (four or five). A best motor level (BML) and worst motor level (WML) were assigned to take into account the situation of asymmetric motor strength. The UEMS is defined as the sum of the muscle grades for the five key muscles in both upper extremities.

All of the subjects included in this study also had neurological examinations performed at 72 h post injury. These examinations were also evaluated, and if the subjects had evolved to neurological levels other than C4–8, or to Frankel grades other than A or B, they were excluded from this study.

The subjects in this study were also classified by their ability to perform six feeding QIF activities at 12 months post injury. These activities were as follows: drinking from a cup, using a fork, cutting food, pouring liquids, opening a jar, and applying spreads. Each task is graded on a scale from zero to four, and thus the maximum score a subject could obtain for the six tasks would be 24. Four subjects included in this study were missing a score for one of the feeding tasks at 12 months. However, since the scores for the task were exactly the same when the subjects were evaluated at 6 months and at 18 months, this score was used at the 12 month evaluation.

Spearman correlations of the NL, BML, WML, UEMS, and feeding QIF scores were conducted. *T* tests were then performed to determine the significance of the correlations.²⁰

Results

The 50 subjects in this study consisted of 47 males and three females. The subject age range was from 16 to 68 years. The mechanisms of injury were: 17 diving accidents, 10 motor vehicle accidents, six falls, seven gunshot wounds, two stab wounds, two pedestrians hit by motor vehicles, two farm equipment accidents, and one each from a motorcycle accident, body surfing, ice hockey, and a fight.

On admission to our center, 36 subjects were Frankel grade A and 14 were Frankel grade B. The NLs on admission were as follows: 29 C4, 12 C5, 6 C6, 2 C7, and 1 C8. At 12 months post injury, the NLs were: 1

C3, 25 C4, 10 C5, 8 C6, 2 C7, 3 C8, and 1 T3. At 12 months, the UEMS ranged from 0 to 50, with a median score of 16 and a mean of 19. The QIF scores spanned the available range from 0 to 24 with a median score of 6 and a mean score of 8.7.

The Spearman correlations of the NL, BML, WML and UEMS are shown in Table 1. Both the BML and the WML were more highly correlated to the UEMS than was the NL ($P < 0.001$).

The correlation of the QIF feeding score with the NL was 0.56. The correlation of the UEMS score to the QIF (0.78) was significantly greater than that of the NL ($P < 0.01$). The BML and the WML had superior correlations to the QIF, 0.74 and 0.72, respectively, than did the NL ($P < 0.05$). The correlation of the UEMS to the QIF was not significantly better than that of the BML or the WML ($P = 0.1$).

In our subject population, the C4 NL was the largest group (25 at 12 months). In 22 of these 25 subjects, the NL was in fact a sensory level. When these subjects were classified by the BML, the levels were as follows: 3 C4, 9 C5, 10 C6, and 2 C7, 1 T1. Despite being classified as the same NL, these subjects had a range of functional motor power in at least one upper extremity from the C4 to the T1 motor level. Motor scores ranged from 0 to 43. Furthermore, scores of feeding abilities ranged from 0 to 22, or almost the entire range of the feeding scale.

Discussion

The superior correlation of the ML and motor score to the performance of feeding activities over that of the NL has been demonstrated in a select group of patients. Our results suggest that for estimating disability, a measure of the motor impairment—either the ML or the UEMS—is more important than the NL. A significantly greater correlation was found between the performance of feeding activities and the measures of motor impairment than between feeding and the NL.

Only individuals with motor complete injuries were included in this study. Patients with incomplete injuries may show a different pattern. Other authors have shown that FIM scores for SCI patients with Frankel A, B and C injuries differ from those with Frankel D injuries.^{21,22} However, a recent report by Iizuka²³ demonstrated that hand function was affected more

severely than proximal arm function in those with a central cord syndrome, regardless of the cervical NL. This suggests that the NL will be a poor indicator of self care function in the incompletely paralyzed patient as well.

A limitation of the study is that it looked solely at feeding activities. The results concur with the prior work of Zafonte *et al*,¹⁶ in which the items in the feeding portion of the QIF seemed to distinguish between levels of tetraplegia. Both ML and UEMS were more highly correlated with feeding abilities than was the NL. Further work is needed to determine if the advantage of motor score over NL holds with other self care activities.

This study did not look at the added contribution of sensation to the performance of functional activities. A study by Ejekkar *et al*²⁴ using the Moberg classification and the Sollerman hand function test found that those tetraplegics with tactile gnosis had better spontaneous hand function as well as a better response to reconstructive surgery. Other work also suggests that sensation contributes to self care function in tetraplegics with similar strength.²⁵ However the high correlation between the motor measures and the QIF in the present study indicates that motor function is the primary predictor of self care function, with a smaller contribution from sensation. This study was not large enough to look at the contribution of sensation by motor level.

This report demonstrates the importance of detailed descriptions of the neurological status in studies involving subjects with SCI. Often there is a discrepancy between the sensory and the motor level on one side. In 64% of our subjects the single NL at 12 months was determined by the sensory level. The BML was as much as five levels lower than the NL. Side-to-side asymmetries also contribute to differences in these levels. These findings are in agreement with those of Waters *et al*,¹⁵ who found that at 1 year the ML corresponded to the light touch and sharp/dull sensory levels only 40% and 33% of the time, respectively. Because of the lack of agreement between sensory and motor levels, reports which do not carefully define 'level' of SCI are difficult to interpret.^{11,14}

Why is this important? In order to evaluate change, it is helpful to reduce the amount of error in measurements.²⁶ The wide range of functional outcomes seen when classifying patients by NL makes it difficult to separate improvements in function from 'noise', or variance, in the measurement. The ML appears to be a more precise measure of functional neurological impairment than the sensory level. The improved correlation of ML with function implies that gains in self care function may be detected more readily when compared to gains in ML or motor score than when compared to changes in NL.

That the ML predicts current self care function better than the NL does not mean that the key muscle is necessarily responsible for the improved function. It is only one of a number of muscles that improve in strength with improvement in ML. For example, compared with patients designated as a C5 ML, those

Table 1 Spearman correlations of neurological level with motor level and motor score

	NL	BML	WML
BML	0.60		
WML	0.69	0.87	
UEMS	0.66	0.96*	0.92*

*Correlation significantly greater than that of NL/UEMS, $P < 0.001$

NL = neurological level; BML = best motor level; WML = worst motor level; UEMS = upper extremity motor score

with a C6 ML usually have functioning pronators as well as wrist extensors. The pronators are important in maintaining the hand in the proper orientation for using a fork or spoon.

It is unclear why the sensory level is a poorer indicator of function than the ML. Sensation may recover differently than strength in cervical SCI. Eschbach *et al* (27) found that only one of 12 subjects with a complete SCI and a C4 sensory level had improvement in the sensory level. In contrast, the majority of patients with cervical SCI gain a ML.^{28,29} Perhaps sensation is sensitive to subtle deficits in the spinal cord. Both light touch and pin sensation must be normal in order to have a normal sensory level. The pathways involved in these modalities are distributed throughout the spinal cord. In contrast, the motor pathways are located in the anterior cord. Furthermore, at the level of injury, motor recovery can occur via peripheral mechanisms (sprouting and muscle hypertrophy), making the ML relatively insensitive to mild or moderate damage in the root or the cord.

In summary, the NL is an imprecise descriptor of the degree of functional loss in SCI. The ML is better correlated to the degree of impairment, as measured by the motor score, and the degree of feeding disability, as measured by the QIF. The NL by itself should not be used to describe the level of injury in SCI unless the lesion is symmetrical. When there are asymmetries in neurological function, separate right and left sensory and motor levels are preferred. The motor score may be the best indicator of functional abilities in complete patients.

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