

Prognostic Value of Pinprick Preservation in Motor Complete, Sensory Incomplete Spinal Cord Injury

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ABSTRACT. Oleson CV, Burns AS, Ditunno JF, Geisler FH, Coleman WP. Prognostic value of pinprick preservation in motor complete, sensory incomplete spinal cord injury. *Arch Phys Med Rehabil* 2005;86:988-92.

Objective: To assess sacral and lower-extremity pinprick preservation as prognostic indicators for ambulation in motor complete, sensory incomplete spinal cord injury (SCI).

Design: Retrospective analysis.

Setting: Twenty-eight tertiary care centers in the United States and Canada.

Participants: Subjects (N=131; mean age, 31.6y) with motor complete, sensory incomplete SCI.

Interventions: Not applicable.

Main Outcome Measure: Ambulation at 26 and 52 weeks postinjury (modified Benzol scale).

Results: A higher percentage of subjects with sacral pinprick preservation at baseline were ambulating at 26 (39.4% vs 28.3%) and 52 weeks (53.6% vs 41.5%). This finding did not reach statistical significance. The presence of sacral pinprick preservation at 4 weeks postinjury was significant for predicting ambulation at 52 weeks postinjury (36.0% vs 4.4%, $P=.011$) and approached significance at 26 weeks (15.2% vs 0.0%, $P=.056$). Significant differences in ambulation rates were also observed between subjects, based on the presence of baseline lower-extremity pinprick preservation ($\geq 50\%$ of lower-extremity L2-S1 dermatomes) at both 26 (50.0% vs 28.8%, $P=.048$) and 52 weeks (66.7% vs 40.3%, $P=.023$) after injury.

Conclusions: Baseline lower-extremity pinprick preservation and sacral pinprick preservation at 4 weeks postinjury are associated with an improved prognosis for ambulation.

Key Words: Prognosis; Rehabilitation; Spinal cord injuries; Walking.

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TRAUMATIC SPINAL CORD INJURY affects approximately 11,000 people annually in the United States, with a prevalence estimated at 183,000 to 230,000.¹ The devastating and often permanent nature of spinal cord injury (SCI) presents physical and psychologic challenges as well as social and economic changes to affected individuals, their families, and greater society. Early identification of the precise location and severity of each patient's neurologic impairment can permit improved understanding of the patient's prognosis—an understanding that leads, in turn, to appropriate and timely development of overall care plans, surgical or pharmacologic interventions, and earlier procurement of equipment. Being able to offer an accurate prognosis for functional outcome similarly permits the injured individuals, their families, and caregivers to develop safe and realistic discharge plans and to use available health care dollars in a more efficient manner.

Complete SCI constitutes the most severe form, with only 2% to 3% of such patients recovering to American Spinal Injury Association (ASIA) grade D status at 1 year after injury.² Incomplete injuries have a variable prognosis, with large differences observed between individuals. These differences are particularly evident for the category of patients with motor complete, sensory incomplete SCI, which represents a small but significant percentage of the total SCI population. Such patients have some sensory preservation through the sacral segments but lack any volitional motor function below the zone of injury. Because such patterns are found in only 10.3% of SCI cases per year,³ this subset of patients has been studied less thoroughly than other groups.

Evidence in the literature suggests that the mode of sensory sparing, specifically pinprick preservation, may be an important factor in predicting recovery in persons with motor complete, sensory incomplete SCI.⁴⁻⁶ Previous studies⁴⁻⁶ are limited by the low number of subjects (from 10 to 27). Furthermore, comparisons between the studies are hindered by differences between the methods of classification (ie, Frankel scale vs the International Standards for the Neurological Classification of Spinal Cord Injury [International Standards]).

METHODS

We assessed pinprick preservation as a prognostic indicator for the recovery of walking ability in motor complete, sensory incomplete traumatic SCI. Study subjects were identified from the multicenter GM-1 ganglioside (Sygen) clinical trial, a randomized, placebo-controlled clinical investigation for which results have been previously reported.⁷⁻⁹ From 1992 to 1997, 760 subjects were enrolled from 28 centers in North America. Data on neurologic recovery was prospectively collected at specified intervals by trained examiners.⁷⁻⁹ Participants were assigned ASIA impairment grades from A to D according to the International Standards.¹⁰

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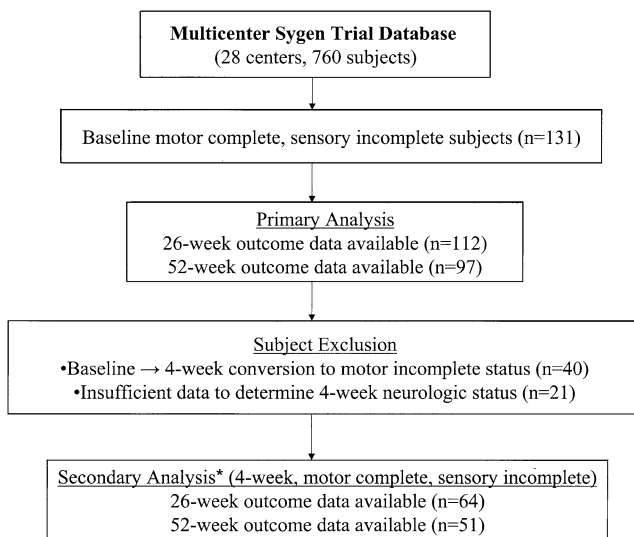


Fig 1. Overall study sample and analysis group subsets. *Maximum possible n (sample size) following subject exclusion was 70.

ASIA grade B persons are defined as those with sensory but not motor sparing below the neurologic injury and their examination must include some degree of sensation in the lowest sacral segments (S4-5). Continuity of sensory preservation between the neurologic level of injury and S4-5 is not required, and sacral sparing may be in the form of either deep anal sensation or, alternatively, light touch or pin in the S4-5 dermatome. According to this definition, our initial cohort consisted of 131 subjects classified with ASIA grade B SCI at study enrollment. Missing data precluded the inclusion of some of these subjects in further analysis, with the exact numbers being dependent on the specific independent and dependent variables of interest (fig 1).

Control subjects, who were not administered GM-1 ganglioside but did receive methylprednisolone according to National Acute Spinal Cord Injury Study II guidelines,¹¹ and experimental subjects, who received both methylprednisolone and GM-1 ganglioside, were combined for the analysis of functional outcomes. This decision was made after initial review failed to reveal significant differences between control and experimental arms at an α level of .05 for the outcome of interest, walking ability. Along with placebo versus control, other independent variables studied were sacral pinprick discrimination and lower-extremity pinprick preservation.

Pinprick appreciation was tested according to the guidelines given in the International Standards.¹⁰ Each dermatome was graded from 0 to 2 as follows: 0 if absent, 1 if present but impaired, or 2 if present and normal, in comparison to pin appreciation in the face. A person who can detect touch or pressure with a pin yet lacks the ability to differentiate this sensation from light touch with a blunt instrument is given a grade of 0 for the affected dermatome.¹⁰ For a grade of 1, pinprick sensation could be subjectively abnormal as long as the ability to reliably distinguish pinprick from light touch remained. Sacral pinprick preservation was defined as the ability to distinguish pinprick from light touch (grade 1 or 2) unilaterally or bilaterally in the S4-5 dermatomes. To eliminate subjects having possible cauda equina injuries from the study, all patients included had a bony level of injury rostral to T10.

Pinprick preservation in the lower extremities was defined as the preservation of pinprick–light touch distinction (grade 1 or

2) in a minimum of 5 of the 10 lower-extremity dermatomes from L2-S1. These dermatomes correspond to the lower-extremity myotomes tested in the International Standards.¹⁰ Our rationale was based on the theory that if pinprick was preserved in a given dermatome, motor return in a corresponding myotome may be more likely.¹² The 50% or more threshold was prospectively selected because it would intuitively be easy for clinicians to replicate.

The outcome of interest was walking ability at 26 weeks and 52 weeks. This was assessed by using the Benzel scale (appendix 1), which scores ambulation from I to VII. Grade IV represents the presence of useful motor ability (ie, assist in transfers) but subjects are unable to ambulate. Grade V is the first level where ambulation is observed and represents the ability to walk 7.5m (25ft) with or without assistance. Patients in this category lack both mobility and endurance. Grade VI was assigned to those who could ambulate 45m (150ft) or more, without assistive devices or significant limitations in stamina. Patients given a grade VII rating are neurologically intact, with the exception of minimal deficits that create no functional impediments to gait. Such patients must be able to ambulate without assistive devices or aid from other individuals. The Benzel grades are not mutually exclusive; therefore, those patients classified as Benzel grade VI have also fulfilled the lesser criteria required for classification in the Benzel grade V category. Consequently, patients who are graded as Benzel grade VI in this report are also included in the Benzel grade V sample, but the converse would not hold true.

Study subjects were divided into appropriate groups based on the status of the predictive variables (sacral pinprick discrimination, lower-extremity pinprick preservation) at baseline assessment, which was within 72 hours of injury. Because we also were interested in the prognostic value of these variables in subjects who remained ASIA grade B at 4 weeks, these subjects were grouped as before according to the status of the predictive variables at 4 weeks. Therefore, the subjects assessed at 4 weeks are a subset of those assessed at the onset of injury. As shown in figure 1, the overall number of subjects is smaller because of the exclusion of subjects who progressed to ASIA grade C or D between baseline assessment and 4 weeks. For all groups, differences in walking ability, at both 26 and 52 weeks, were tested for statistical significance using the 2-tailed Fisher exact test ($\alpha=.05$). Because of missing data, sample sizes vary slightly between groups, based on the independent and dependent variables of interest.

RESULTS

Demographics

The entire GM-1 ganglioside trial involved more cervical (579/760=76.2%) than thoracic (181/760) injuries; similarly the 131 ASIA grade B patients had predominantly cervical SCI (86.3%), with the remaining 13.7% having thoracic level injuries. The most common cause of injury was motor vehicle crash (45.8%), followed by injury related to water (19.1%) and falls (14.5%). There were 106 men (80.9%) and 25 women (19.1%). The maximum age for enrollment in the GM-1 ganglioside trial was 69 years, and the minimum was 15 years. Our subset of interest included this full range, and it had a mean age of 31.6 ± 13.6 years (table 1).

Drug Versus Placebo

Of the original 131 patients, 112 had full data available for analysis at 26 weeks. Of these, 65 subjects received GM-1 ganglioside along with methylprednisolone, whereas 47 other

Table 1: Subject Demographics (N=131)

Mean age (y)	31.6±13.6
Sex	
Male	106 (80.9)
Female	25 (19.1)
Bony level of injury	
Cervical	113 (86.3)
Thoracic	18 (13.7)
Etiology of injury	
MVC	60 (45.8)
Water-related	26 (19.9)
Falls	19 (14.5)
Other	26 (19.8)

NOTE. Values are mean ± standard deviation or n (%).
Abbreviation: MVC, motor vehicle collision.

subjects (controls) received only methylprednisolone. Results of functional outcomes of walking at 26 weeks postinjury indicated no significant difference in outcomes between the 2 groups (table 2). Approximately 35% of each group attained a minimum ambulatory capacity of 7.5m (Benzel grade ≥V). Twenty percent of patients receiving the drug and 12.8% of controls regained independent ambulation of at least 45m (Benzel grade ≥VI), a difference that was not significant ($P=.45$).

Available data allowed analysis for 97 subjects at 52 weeks. At this time point, 52% of those who received GM-1 ganglioside and 44% of the controls achieved limited ambulation of at least 7.5m ($P=.54$). Independent ambulation equivalent to a Benzel grade of VI or greater was achieved by 26% of those receiving the drug and 20% of the controls ($P=.63$). In neither case were the differences observed between groups statistically significant. Given the similarity of functional outcomes, we combined subjects who did and did not receive GM-1 ganglioside as previously described in the methods.

Sacral Pinprick

Walking ability as a function of initial sacral pinprick preservation was evaluated at 26 weeks and at 52 weeks postinjury.

Fifteen patients were dropped from analysis between 26 and 52 weeks, as explained in the preceding section. Although a higher percentage of subjects with sacral pinprick–light touch discrimination (39.4% vs 28.3%) were ambulating at 26 weeks, the results did not reach significance ($P=.24$). The differences in subjects with and without initial pinprick–light touch differentiation (53.6% vs 41.5%) were similarly inconclusive at 52 weeks postinjury ($P=.31$).

At 4 weeks after injury, the initial cohort was reanalyzed for those subjects with and without sacral pinprick preservation. At this evaluation, 61 of the initial 112 were available for study because many had progressed to a higher ASIA classification. Furthermore, some patients initially without sacral pinprick had subsequently regained this sensation. There were 33 patients with pinprick preservation and 28 lacking it. Differences in walking ability at 26 weeks for each group approached significance for Benzel grades of V or higher (15.2% vs 0.0%, $P=.06$) and were not significant for Benzel grades of VI or higher (3.0% vs 0.0%, $P=1.00$).

Walking outcomes at 52 weeks were available for 48 patients (25 with pinprick preservation, 23 without this ability). Walking ability was significant (36.0% vs 4.4%, $P=.01$) for limited ambulation (Benzel grade ≥V) but not for a higher degree of ambulation (Benzel grade ≥VI).

Lower-Extremity Dermatome Pinprick From L2-S1

At initial assessment, 32 patients had preserved pinprick in 50% or more of the dermatomes corresponding to key lower-extremity myotomes and 80 subjects had pinprick preservation in less than 50% of these dermatomes. Evaluation of walking ability at 26 weeks demonstrated significant differences between the groups. Fifty percent of the subjects having lower-extremity pinprick by the previously mentioned criteria versus 28.8% of those without the criteria achieved a Benzel grade V or greater ($P=.05$). Functional ambulation of grade VI or greater was observed in 31.3% of subjects with lower-extremity pinprick versus 11.3% of subjects lacking pinprick ($P=.03$). At 52 weeks, 97 patients, 30 with lower-extremity pinprick preservation and 67 who lacked this modality, were available

Table 2: Benzel Scores of Ambulatory Function by Treatment Group, Sacral Pinprick, and Lower-Extremity Pinprick

Study Cohort	26-Week Outcomes (n=112)				52-Week Outcomes (n=97)			
	Benzel Grade ≥V (%)	<i>P</i>	Benzel Grade ≥VI (%)	<i>P</i>	Benzel Grade ≥V (%)	<i>P</i>	Benzel Grade ≥VI	<i>P</i>
Treatment Group								
Drug	23/65 (35.5)	1.00	13/65 (20.0)	0.45	30/58 (51.7)	0.54	15/58 (25.9)	0.63
Placebo	16/47 (34.0)		6/47 (12.8)		17/39 (43.6)		8/39 (20.5)	
Sacral PP								
Baseline								
Yes	26/66 (39.4)	0.24	12/66 (18.2)	0.80	30/56 (53.6)	0.31	16/56 (28.6)	0.23
No	13/46 (28.3)		7/46 (15.2)		17/41 (41.5)		7/41 (17.1)	
4 weeks								
Yes	5/33 (15.2)	0.06	1/33 (3.0)	1.00	9/25 (36.0)	0.01	2/25 (8.0)	0.49
No	0/28 (0.0)		0/28 (0.0)		1/23 (4.4)		0/23 (0.0)	
LE × PP (%)								
Baseline								
<50	23/80 (28.8)	0.05	9/80 (11.3)	0.03	27/67 (40.3)	0.02	11/67 (16.4)	0.02
≥50	16/32 (50.0)		10/32 (31.3)		20/30 (66.7)		12/30 (40.0)	
4 weeks								
<50	3/41 (7.3)	0.66	0/41 (0.0)	0.36	4/32 (12.5)	0.07	1/32 (3.1)	1.00
≥50	3/23 (13.0)		1/23 (4.4)		7/19 (36.8)		1/19 (5.3)	

NOTE. Statistically significant values are in boldface.
Abbreviations: LE, lower extremity; PP, pinprick.

for follow-up. At this latter evaluation point, the between-group differences were significant for subjects reaching Benzel grade V or higher (66.7% vs 40.3%, $P=.02$) and grade VI or higher (40.0% vs 16.4%, $P=.02$) scores.

As we had done with sacral pinprick, we reevaluated subjects for pinprick sensation in key lower-extremity dermatomes at 4 weeks postinjury. We had 64 patients available for study, 23 with pinprick preservation in at least 50% of the L2-S1 dermatomes and 41 who failed to reach the 50% criteria. At neither the 26-week nor the 52-week assessment of walking ability were differences statistically significant among those with and without lower-extremity pinprick 4 weeks postinjury; although the difference approached significance for grade V or higher Benzel grades at 52 weeks (36.8% vs 12.5%, $P=.08$).

DISCUSSION

In the last 20 years, various investigators^{4-6,12,13} have reported a relation between pinprick preservation and recovery in motor complete, sensory incomplete SCI.^{4-6,12,13} The study by Foo et al,⁵ which used the Frankel classification, found that 4 of 6 (66%) patients with at least partial pinprick preservation in the lowest sacral segments, and often in many additional dermatomes, reached D status and were able to ambulate with assistive devices, compared with only 1 of 7 (14%) who lacked initial pinprick appreciation but had intact light touch and proprioception. Our work differed from the work of Foo in that all patients in the Sygen database were evaluated within 72 hours of injury, whereas those in the Foo study were initially assessed up to 6 weeks postinjury. Regardless, the rate of ambulation was comparable to that found in our study (67%).

Waters et al⁶ reported motor recovery in the lower extremities of 13 motor complete, sensory incomplete SCIs. Of the 5 patients showing light touch in S4-5 but lacking bilateral pinprick in this dermatome, none recovered lower-extremity motor function from initial evaluation to 1 year postinjury. In contrast, 8 of 8 patients with sacral light touch–pinprick differentiation achieved some lower-extremity motor recovery, with 3 of 8 having 3/5 motor strength or better in some lower-extremity muscle groups by 1 year postinjury. Results for ambulation were not reported. Small numbers of subjects also limit the comparison of these results to our study.

In the largest series to date, Crozier et al⁴ retrospectively studied 27 motor complete, sensory incomplete patients. They found that 8 of 9 (89%) patients with initial pinprick preservation below the neurologic level of injury achieved community ambulation compared with only 2 of 18 (11%) who lacked such preservation. Although Crozier's work showed a marked difference in functional outcome between those with and without pinprick preservation, our investigation failed to yield as robust a difference. This finding exists despite our study having a longer interval before outcome measurement (1y) compared with Crozier's measurement at discharge from the rehabilitation facility. We found a community ambulation (Benzel grade \geq VI) rate of 40% at 12 months in subjects with lower-extremity pinprick preservation, compared with 16% in those without pinprick preservation. Observed differences could be partially attributable to chance, given the differing sample sizes: 27 subjects versus 131 subjects.

Another issue that hampers direct comparison is the different definitions for pinprick preservation; Crozier's study defined it as partial or complete pinprick appreciation below the zone of injury. Both studies defined a baseline assessment as measurements taken within 72 hours of injury. As has been reported,¹⁴ accurate assessment of subjects can be challenging during this time. Furthermore, performing a reliable assessment is even more difficult for tetraplegic subjects because they often re-

quire ventilatory support, which impacts communication. Although the percentage of tetraplegic subjects is not reported in the Crozier study, 86% of our subjects were in this category.

Katoh and El Masry¹³ reviewed 21 patients with an initial Frankel B impairment classification. The overall rate of ambulation was 33% (7/21). Seventy-five percent (6/8) of patients with either sharp or dull sensory appreciation in S4-5 combined with some degree of light touch–pinprick differentiation between the zone of injury and the lowest sacral segments were able to ambulate in some capacity. These rates are comparable to those reported in our study. The extent of pinprick preservation was further characterized by the continuity of pinprick preservation from the neurologic level of injury through the sacral segments. The best outcomes in terms of walking ability were shown among the patients with pinprick appreciation throughout all dermatomes of evaluation. We also found that the existence and distribution of pinprick preservation below the neurologic level of injury is valuable in predicting functional outcome. Of those with pinprick in 50% or more of the L2-S1 dermatomes at presentation, 20 of 30 patients or 67% could ambulate at least household distances 12 months after injury. In addition, 12 of those 20 (60% of the Benzel \geq V category or 40% of all individuals) could move 45m.

The overall rates of ambulation at 52 weeks for subjects in our study were 48% for at least household ambulation (Benzel grade \geq V) and 24% for community ambulation (Benzel grade \geq VI). Although subjects with sacral pinprick sensation had slightly higher rates of ambulation, this number did not reach statistical significance for most comparisons (see table 2), the exception being subjects with sacral pinprick preservation at 4 weeks postinjury. In contrast to sacral preservation, our findings strongly support the value of lower-extremity pinprick preservation at presentation for ambulatory prognosis. However, the presence of similar light touch–pinprick differentiation at 4 weeks postinjury was not significant. It is possible that people with initial lower-extremity pinprick preservation who ultimately ambulate rapidly progress to higher ASIA impairment grades (ie, C, D) during the first month. Therefore, people who remain motor complete at 4 weeks, but continue to have some degree of lower-extremity pinprick differentiation, may have a reduced chance of functional motor recovery.

Although the number of comparisons increases the likelihood of an individual result reaching significance ($P\leq.05$) by chance, our overall findings support the concept that pinprick preservation is useful in predicting motor recovery. All the comparisons involving baseline lower-extremity pinprick were statistically significant, and the presence of sacral pinprick sensation at 4 weeks was significant for the 52-week outcome.

Inherent to this investigation were several limitations of the Sygen database. They include the selection of study centers in large cities in which certain types of trauma may be overrepresented relative to the general population. The study population of 760 subjects permitted us to draw a larger sample than would be possible had we used studies from a single SCI center. Although the reliance on major trauma centers may limit the application of this study to other settings, we believe the benefits of large sample sizes and consistent data collection methods outweigh that disadvantage. Additional limitations are the high number of cervical injuries in our population, exclusion of polytrauma as well as penetrating injuries, and elimination of medical comorbidities.

CONCLUSIONS

The ability to sense pinprick in the lower extremities within 72 hours of injury is associated with an improved prognosis for the recovery of ambulatory function in persons with initial

motor complete, sensory incomplete SCI. Persons with pinprick discrimination in the S4-5 dermatome at 4 weeks postinjury also appear to have an improved prognosis for ambulation, although this finding is less robust. Overall, differences in the rates of ambulation for motor complete, sensory incomplete injuries with and without varying degrees of pinprick preservation are less marked than in prior studies.

APPENDIX 1: MODIFIED BENZEL SCALE

Grade	Description
I	No motor or sensory function is preserved in sacral segments S4-5.
II	Sensory but no motor function is preserved in sacral segments S4-5.
III	Motor function is preserved below the neurologic level, and the majority of key muscles below the neurologic level have a muscle grade <III; unable to walk.
IV	Unable to walk; some functional motor control below the level of the injury that is significantly useful (eg, assist in transfers, etc) but that is not sufficient for independent walking.
V	Limited walking; motor function allows walking with assistance or unassisted, but significant problems secondary to lack of endurance or fear of falling limit patient mobility (must be able to ambulate at least 25 feet).
VI	Unlimited walking; ambulatory without assistance and without significant limitations other than slightly dyscoordinated gait (must be able to ambulate at least 150 feet without a helper).
VII	Neurologically intact with the exception of minimal deficits that cause no functional difficulties (must have a neurologically normal gait and be able to walk without assistance of assistive devices).

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