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ORIGINAL ARTICLE

Relevance of the diagnosis traumatic cervical Brown-Séquard-plus syndrome: an analysis based on the neurological and functional recovery in a prospective cohort of 148 patients

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Study design: Prospective multi-center cohort study.
Objectives: To compare the neurological and functional recovery between tetraplegic Brown-Séquard-plus syndrome (BSPS) and incomplete tetraplegia (non-BSPS).
Setting: European Multicenter Study of Human Spinal Cord Injury (EM-SCI).
Methods: BSPS was defined as a traumatic incomplete spinal cord injury (SCI) with ipsilateral weakness and contralateral loss of pinprick sensation at neurologic levels C2–T1. Acute (0–15 days) and chronic phase (6 or 12 months) were assessed for the American Spinal Injury Association (ASIA) sensory scores, upper extremity motor scores and lower extremity motor scores. Furthermore, chronic phase scores of all Spinal Cord Independence Measure (SCIM) II items were analyzed. Differences in neurological and functional outcome between BSPS patients and non-BSPS patients were calculated using Student's *t*-tests and Wilcoxon signed rank tests.
Results: Out of 148 tetraplegic patients, 30 were diagnosed with BSPS. Patients with an ASIA impairment scale (AIS) B were significantly ($P<0.001$) more identified in non-BSPS patients (25%) compared with BSPS patients (3%), respectively. After 12 months, the median scores for sphincter management of the bladder for both BSPS and non-BSPS patients were 15. Both 25 and 75% quartile median scores were 15 for BSPS patients and 12 and 15 for non-BSPS patients ($P<0.02$). Except for the difference in bladder function, no significant differences were identified in other SCIM II subitems and ASIA motor or sensory scores between BSPS and non-BSPS patients when stratified for injury severity by excluding AIS B patients.
Conclusion: Compared with incomplete tetraplegic patients, patients with cervical BSPS have a similar neurological and functional recovery when matched for the AIS.
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Keywords: Brown-Séquard-plus syndrome; Brown-Séquard syndrome; functional recovery; neurological recovery; spinal cord injury

Introduction

The Brown-Séquard syndrome (BSS) is a syndrome consisting of ipsilateral upper motor neuron paralysis (hemiplegia) and loss of proprioception with contralateral pain and temperature sensation deficits.[1] Common causes of BSS include penetrating trauma, syringomyelia, spinal neoplasms, disc herniation, spinal cord herniation, viral myelitis or blunt injury.[2–4]

Most descriptions of BSS, however, are less pure forms of the syndrome;[4,5] therefore a derivative has been introduced with the term Brown-Séquard-plus syndrome (BSPS).[4,6] BSPS is a spinal cord injury (SCI) with bilateral involvement of upper and/or lower extremities and is defined as an incomplete SCI syndrome with ipsilateral weakness and contralateral loss of pinprick and temperature sensation.[4–6]

According to the International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients, BSS is a syndrome that produces *relatively* greater ipsilateral proprioceptive and motor loss and contralateral loss of sensitivity to pain and temperature.[7] The definition of BSS by the American Spinal Injury Association (ASIA)

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standards is essentially the same as BSPS concept and therefore leads to SCI patients being classified as BSS instead of BSPS. For example, several case reports[8–10] described patients with BSS, however, the reported neurological examinations were not descriptions of the 'classic' BSS.[1] According to Koehler *et al*.,[4] BSS should not be used in incomplete SCI patients with bilateral involvement of upper and/or lower extremities.

The clinical and scientific relevance of incomplete tetraplegic patients being labeled as the not 'classic' BSS or BSPS therefore can be questioned. The reason for defining BSPS may be based on the assumption that patients with BSPS act differently than other incomplete tetraplegic patients with regard to neurological and functional outcome. To date however, there is no clear evidence for this assumption in the literature.

The purpose of this study, therefore, is to compare the neurological and functional recovery between the tetraplegic BSPS and incomplete tetraplegic patients.

Materials and methods

A total of 17 SCI centers prospectively collected information from complete and incomplete traumatic SCI patients between spring 2002 and summer 2008. Data in the European Multicenter Study on Human Spinal Cord Injury (EM-SCI; www.emsci.org) are assessed to establish a multicenter basis for future therapeutic interventions in human SCI. Data in the EM-SCI are collected at four time intervals: 1, 3, 6 and 12 months after the injury. Clinical assessments in the EM-SCI are conducted by certificated neurological and rehabilitation physicians having at least 1 year experience in examining patients with SCI.

Study population

Patients were included in the study whether they had an incomplete traumatic SCI injury (ASIA impairment scale (AIS) B, C or D)[7] at neurologic levels C2–T1. The BSPS was defined as an incomplete syndrome with ipsilateral weakness and contralateral loss of pinprick sensation.[4–6] Differences of >0 between left and right ASIA total motor and total sensory scores were considered asymmetric left–right neurological deficits.

As we were only interested in the neurological and functional recovery of BSPS patients, 'classic' BSS patients were excluded. The definition that was used for BSS is as following: a syndrome consisting of ipsilateral upper motor neuron paralysis (hemiplegia) and loss of proprioception with contralateral pain sensation deficit.[1] Patients with a severe cognitive impairment, peripheral nerve lesion, incomplete database record, nontraumatic spinal cord lesion, polyneuropathy or craniocerebral injury were not included in the EM-SCI database. In patients where chronic phase (12 months) follow-up measurements were not recorded, the 6-months follow-up measurements were used for analysis.

The study protocols were approved by the local ethics committees and the patients gave their informed consent before entering the study.

Neurological outcomes

Neurological examinations were conducted according to the ASIA standards.[11] All patients with completely conducted acute phase examinations (within the first 15 days after the injury), that is, the upper extremity motor score (UEMS), the lower extremity motor score (LEMS), ASIA pin prick score and ASIA light touch scores were included for the analysis. On the basis of ASIA sensory and motor scores, neurological level of injury (NLI) and AIS grade were defined. Acute and chronic phases were assessed for the total upper extremity motor score, the total LEMS, the total ASIA pin prick scores and the total ASIA light touch scores in each patient during follow-up.

Functional outcomes

The Spinal Cord Independence Measure (SCIM) is an instrument that focuses on performing everyday tasks, and captures the disability and the impact of disability on the patient's overall medical condition and comfort.[12] The SCIM II[13] consists of three main categories, namely, (1) self-care, (2) respiration and sphincter management and (3) mobility. The chronic phase was assessed for self-care (SCIM II items 1–4), respiration and sphincter management (SCIM II items 5–8), mobility in room and toilet (SCIM II items 9–11) and mobility indoors and outdoors (SCIM II items 12–16) in each patient during follow-up.

Statistics

Descriptive statistics on age, gender and AIS were used to provide general information of the study population. Subanalysis on NLI, AIS (χ^2 analysis) and age (Student's *t*-test) was carried out to identify possible differences between BSPS patients and other incomplete tetraplegia (non-BSPS patients).

The mean ASIA scores were calculated for both acute and chronic phases. The median SCIM II scores were calculated for the chronic phase. Differences in ASIA and SCIM II scores between BSPS and non-BSPS patients were calculated using Student's *t*-tests and Wilcoxon signed rank tests, respectively. The differences were considered statistically significant at $P<0.05$. Data were analyzed using SPSS software (version 16.0, SPSS, Chicago, IL, USA).

Results

Among the 1365 traumatic SCI patients within the EM-SCI database, 228 (17%) met the study criteria (see Figure 1). Follow-up SCIM II measurements and ASIA motor and sensory scores were available in 148 (65%) patients. The mean patient age at time of injury was 48 years (range: 15–88) and 23% were females. Acute phase AIS grades were B ($n=31$, 21%), C ($n=47$, 32%) and D ($n=70$, 47%) (see Table 1).

A total of 52 (4%) SCI patients were identified to have the BSPS. Of these 52 BSPS patients, 7 (14%) patients had 6 months and 23 (44%) patients had 12 months follow-up SCIM II measurements and ASIA motor and sensory scores. Non-BSPS was identified in 176 (13%) SCI patients. Of these

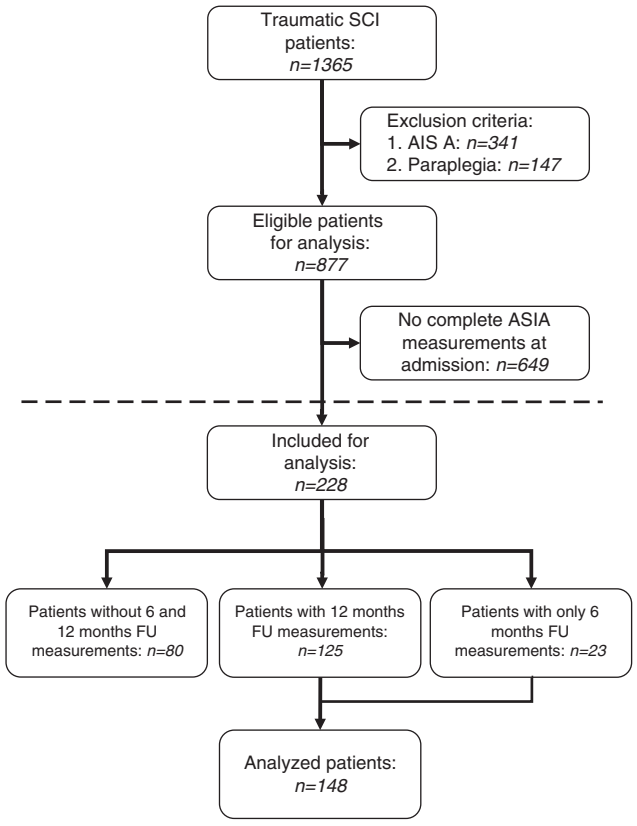

Figure 1 Flowchart of patients in the EM-SCI database of eligible patients included for analysis. Period of inclusion was January 2002–October 2008. SCI, spinal cord injury; ASIA, American Spinal Injury Association; AIS, ASIA impairment scale; FU, follow-up.

176 non-BSPS patients, 16 (9%) patients had 6 months and 102 (58%) patients had 12 months follow-up SCIM II measurements and ASIA motor and sensory scores. No SCI patient was identified to have BSS (Table 1).

The range difference in left and right ASIA total motor score at baseline and follow-up was 1–30 (mean 11.4; s.d. 9.8) and 0–25 (mean 4.0; s.d. 10.4), respectively. The range difference in left and right ASIA pin prick scores at baseline and follow-up was 1–24 (mean 8.4; s.d. 7.9) and 0–41 (mean 10.4; s.d. 5.6), respectively.

Subanalysis identified no differences for age, NLI, AIS C and AIS D between BSPS and non-BSPS patients. However, motor complete SCI's (AIS B) were significantly ($P<0.001$) more identified in non-BSPS patients ($n=30$) compared with BSPS patients ($n=1$).

In BSPS patients, the following subitems during the chronic phase showed significant differences compared with non-BSPS patients: bathing (upper body), grooming, sphincter management (bladder and bowel), use of toilet, mobility indoors, mobility for moderate distances, mobility outdoors and transfers from wheelchair to car (Table 2). In addition, BSPS patients had higher mean LEMSs during acute and chronic phases compared with non-BSPS patients (Table 3).

Compared with 30 non-BSPS patients, only one BSPS patient was identified to have an AIS B (Table 1). Therefore, after excluding AIS B patients we repeated our analyses. Subanalysis identified no differences for age, AIS and NLI between BSPS and non-BSPS patients. Except for sphincter management of the bladder ($P<0.02$), no significant differences in other SCIM II subitems and ASIA motor or sensory scores were identified between 29 BSPS patients and 88 non-BSPS patients. After 12 months, the median scores for sphincter management of the bladder for both BSPS and non-BSPS patients were 15. Both 25 and 75% quartile median scores were 15 for BSPS patients and 12 and 15 for non-BSPS patients.

Table 1 Demographic data of 148 patients

Characteristics	*BSPS*	*Non-BSPS*
Patients (*n*)	30	118
Age, years; mean ± s.d.	47 ± 17	49 ± 19
Male (*n*)	23	91
Left sided (*n*)	14	37
NLI (n and %)		
C2	2 (7%)	3 (3%)
C3	0	12 (10%)
C4	14 (47%)	42 (36%)
C5	11 (37%)	43 (36%)
C6	3 (10%)	14 (12%)
C7	0	3 (3%)
C8	0	1 (1%)
T1	0	0
AIS (n and %)		
B	1 (3%)	30 (25%)
C	8 (27%)	39 (33%)
D	21 (70%)	49 (42%)

Abbreviations: AIS, ASIA impairment scale; BSPS, Brown-Séquard-plus syndrome; NLI, neurological level of injury; non-BSPS, incomplete tetraplegia.

Discussion

In this study, we compared the differences in neurological and functional recovery between tetraplegic BSPS and non-BSPS patients and identified that patients with BSPS or non-BSPS have a similar neurological and functional recovery when matched for the AIS.

Our results showed a favourable recovery of bathing of the upper body, grooming, sphincter management, use of toilet, mobility indoors and outdoors (SCIM II items 12–14 and item 16) and the LEMS in BSPS patients compared with other incomplete tetraplegic patients. All these significant differences became nonsignificant when the groups were stratified for injury severity by excluding patients with AIS B. However, sphincter management of the bladder seemed to be significantly better in BSPS patients after exclusion of the AIS B patients.

This study shows that the favourable neurological and functional recovery in patients with BSPS is predominantly determined by injury severity. In other words, compared with BSPS patients, more non-BSPS patients had an AIS B. As patients with an AIS B generally have a neurological and functional recovery to a much lesser degree than patients

Table 2 SCIM scores in 30 cervical BSPS patients compared with 118 cervical non-BSPS patients after 12 months

SCIM II subitems	*BSPS*		*Non-BSPS*			P-*values*
	Maximal score	*Median*	*Percentiles (25–75%)*	*Median*	*Percentiles (25–75%)*	
Self-care						
Feeding	4	4	(3–4)	4	(3–4)	0.108
Bathing (upper body)	3	**3**[a]	**(3–3)**	**3**	**(1–3)**	0.008
Bathing (lower body)	3	3	(2–3)	3	(1–3)	0.067
Dressing (upper body)	3	3	(2–3)	3	(1–3)	0.312
Dressing (lower body)	3	3	(2–3)	3	(1–3)	0.103
Grooming	4	**4**[a]	**(4–4)**	**4**	**(3–4)**	0.039
Respiration and sphinter management						
Respiration	10	Constant[b]	Constant	10	(10–10)	0.474
Sphincter management (bladder)	15	**15**[a]	**(15–15)**	**15**	**(4–15)**	0.003
Sphincter management (bowel)	10	**10**[a]	**(10–10)**	**10**	**(5–10)**	0.011
Use of toilet	5	**5**	**(3.25–5)**	**4.5**	**(0–5)**	0.039
Mobility (room and toilet)						
Motion in bed and sore prevention	6	6	(6–6)	6	(2.75–6)	0.197
Transfers: bed–wheelchair	2	2	(2–2)	2	(1–2)	0.106
Transfers: wheelchair–toilet–tub	2	2	(2–2)	2	(1–2)	0.059
Mobility (indoors and outdoors)						
Mobility indoors	8	**8**[a]	**(7–8)**	**8**	**(2–8)**	0.015
Mobility for moderate distances	8	**8**	**(7–8)**	**6**	**(2–8)**	0.007
Mobility outdoors	8	**8**	**(6.5–8)**	**5**	**(1–8)**	0.005
Stair management	3	3	(2–3)	2	(0–3)	0.166
Transfers: wheelchair–car	3	**3**[a]	**(2.75–3)**	**3**	**(1–3)**	0.034

Abbreviations: BSPS, Brown-Séquard-plus syndrome; non-BSPS, incomplete tetraplegia; SCIM II, Spinal Cord Independence Measure II.
Bold values indicate significant differences.
[a]Statistically significant difference was seen although the median scores were equal.
[b]All patients had the maximal score.

Table 3 ASIA scores in 30 cervical BSPS patients compared with 108 cervical non-BSPS patients

ASIA scores	*BSPS acute*		*95% CI*	*Non-BSPS acute*		P-*values*	*BSPS chronic*		*Non-BSPS chronic*		P-*values*
	Maximal score	*Mean*		*Mean*	*95% CI*		*Mean*	*95% CI*	*Mean*	*95% CI*	
Total UEMS	50	24.2	20.5–27.8	22.8	20.4–25.3	0.603	42.4	39.9–44.9	38.7	36.7–40.8	0.095
Total LEMS	50	**29.0**	**23.1–34.9**	**19.3**	**15.9–22.8**	0.012	**43.2**	**38.7–47.6**	**35.2**	**32.0–38.4**	0.021
Total pin-prick scores	112	67.8	58.2–77.5	65.1	59.6–70.6	0.649	79.5	72.3–86.6	77.6	72.2–82.9	0.733
Total light-touch scores	112	83.0	74.5–91.4	74.6	70.5–78.7	0.072	90.1	83.3–96.8	85.9	82.0–89.9	0.339

Abbreviations: ASIA, American Spinal Injury Association; BSPS, Brown-Séquard-plus syndrome; CI, confidence interval; LEMS, lower extremity motor score; non-BSPS, incomplete tetraplegia; UEMS, upper extremity motor score.
Bold values indicate significant differences.

with an AIS C and AIS D,[14,15] BSPS patients in this study could be expected to have a relatively better recovery than non-BSPS patients. Therefore, compared with incomplete tetraplegic patients, BSPS patients do not have a *better*, but a *similar* neurological and functional recovery if corrected for the injury severity (AIS).

Although no study was identified that investigated the functional and neurological recovery between cervical BSPS and incomplete tetraplegia, two studies reported on the functional recovery in BSPS patients.[6,16] McKinley *et al*.[16] retrospectively reviewed and compared the functional outcomes in patients with SCI syndromes during inpatient rehabilitation. This study[16] used the BSS definition of the International Standards,[7] which is essentially the same as the BSPS concept. Mckinley *et al*.[16] reported on 30 BSPS patients and concluded that cervical BSPS patients seemed to achieve higher functional improvements by discharge compared with patients with the traumatic central cord syndrome.[16] Roth *et al*.[6] retrospectively reviewed the functional outcomes in BSPS patients and concluded that BSPS patients generally have a good prognosis for neurological and functional improvement.[6]

BSPS patients in this study remained to have a better bladder function compared with non-BSPS patients after 12 months. We have no valid explanation why BSPS patients have a better bladder function. Two studies support the finding that BSPS patients have good bladder function after rehabilitation.[6,16] Mckinley *et al*.[16] identified that BSPS patients had the highest levels of independence in bladder function compared with other SCI syndromes. Roth *et al*.[6]

showed that 89% of the 33 BSPS patients had independent bladder function at discharge. We consider the significant, though small, difference in bladder function scores between BSPS and non-BSPS patients in this study to be of little clinical relevance.

Complete hemisection with the classic clinical features of pure BSS[17,18] is rare. This could be a reason that most descriptions of BSS are descriptions of BSPS. In this study, all patients with left–right asymmetric neurological deficits were recognized as BSPS and no patient was identified to have BSS. As quantified criteria for BSS and BSPS are lacking, the diagnosis of BSS and BSPS is based on non-specific criteria and interpretation of physical examination. In addition, classifying the SCI syndromes by means of the current International Standards for Neurological and Functional Classification of Spinal Cord Injury Patients[7] is known to be challenging.[19] The utility of currently applied BSS and BSPS diagnostic criteria therefore can be considered as limited.

As our data showed that the neurological and functional recovery in tetraplegic BSPS patients is comparable to that of other incomplete tetraplegic patients, classifying patients according to the currently used BSS[7] or BSPS definitions[6] seems to be clinically irrelevant. However, we suggest that the term *relatively* in the current BSS definition[7] should be abandoned and replaced by specific diagnostic criteria. An univocal quantified definition should result in a clear-cut classification for BSS. In addition, we believe that it is not necessary to define the BSPS as a separate SCI syndrome apart from BSS.

Some limitations of this study warrant consideration. Several putative confounders such as treatment regimens, comorbidities, rehabilitation programs and walking aids have not been registered within the EM-SCI database. Furthermore, we presented the results from the second version of the SCIM, which is in use in the centers of the EM-SCI. However, a third version of the SCIM has been validated recently.[20] The third version includes a new item (transfer: ground–wheelchair) and the scoring of various subitems has been slightly modified, but the scores for the overall categories (self-care, respiration and sphincter management, and mobility) are unchanged. We believe that the results of our study are supposed to be independent of the SCIM version that was used, although the refinement of scaling of some subitems might result in the description of more nuances during functional recovery.

Conclusion

When matched for injury severity, cervical BSPS patients seemed to have a similar neurological and functional recovery compared with patients with an incomplete tetraplegia.

Conflict of interest

The authors declare no conflict of interest.

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