ORIGINAL ARTICLE

Traumatic and non-traumatic spinal cord-injured patients in Quebec, Canada. Part 2: biochemical profile

P Rouleau^{1,2} and PA Guertin^{1,2,3,4}

¹Centre Hospitalier Universitaire de Quebec, Neuroscience Unit, Quebec City, Quebec, Canada; ²Neurospina Therapeutics, Quebec City, Quebec, Canada; ³Department of Psychiatry and Neuroscience, Université Laval, Faculty of Medicine, Quebec City, Quebec, Canada and ⁴Nordic Life Science Pipeline, Quebec City, Quebec, Canada

Study design: Community-based, cross-sectional study.

Objectives: This study aimed at examining and comparing biochemical profiles (blood and urine) of traumatic and non-traumatic spinal cord-injured patients (TSCIs vs NTSCIs).

Setting: The Interval Rehabilitation Center, Trois-Rivières, Province of Quebec, Canada

Methods: Medical records from a cohort of 175 chronic spinal cord-injured patients (94 TSCI and 81 NTSCI individuals) were thoroughly studied.

Results: Augmentations over time of red blood cell (erythrocyte), hematocrit and hemoglobin levels were generally found after spinal cord injury (SCI), specifically in NTSCI patients (late vs early chronic). In contrast, although leukocyte levels generally decreased over time after SCI, higher lymphocyte levels were detected only in NTSCI patients (late vs early chronic). Higher total cholesterol, triglyceride, high-density lipoprotein-cholesterol (HDL-C) and low-density lipoprotein-cholesterol (LDL-C), protein and albumin serum levels were generally found over time after SCI, again, specifically in chronic NTSCI patients (late vs early chronic), whereas increased (twofold) nitrite and decreased (twofold) urobilinogen urine levels were found specifically in TSCI individuals (late vs early chronic).

Conclusion: Clear differences were reported between subgroups of SCI patients strongly supporting the idea that therapeutic approaches aimed to treat these problems should be specifically designed for each type of patients (that is, NTSCI vs TSCI or early vs late chronic patients).

Spinal Cord (2010) 48, 819–824; doi:10.1038/sc.2010.42; published online 11 May 2010

Keywords: biochemical; biomarker; urine; blood; patient

Introduction

Traumatic spinal cord injury (TSCI) is associated with an immediate and generally irreversible loss of sensory and voluntary motor functions. Non-traumatic spinal cord injury (NTSCI) also leads to sensory and motor function losses, although these occur progressively rather than immediately. Both groups of SCI patients have generally been reported to suffer from multiple health problems or so-called secondary complications (for example, muscle atrophy, osteoporosis, skin ulcers, urinary tract infections, chronic pain, hypotension and other metabolic problems; see companion paper no.1 for references). However, the extent of secondary complications in NTSCI patients remains incompletely understood and time-dependent or direct comparisons of biochemical profiles (many of which are biomarkers) between TSCI and NTSCI patients are virtually inexistent. For

instance, abnormally low erythrocyte, hemoglobin (Hb) and hematocrit (Ht) levels in acute or early chronic TSCI patients, and dyslipidemia (for example, abnormally high low-density lipoprotein-cholesterol (LDL-C) and low high-density lipoprotein-cholesterol (HDL-C) levels) in late TSCI subjects, have clearly been reported although comparable changes in NTSCI remain unclear.^{1–3} Dysregulated hormonal levels (for example, growth hormone and testosterone) have been shown to change over time and to be linked to depression in TSCI patients (not studied in NTSCI subjects).^{4,5} Studied primarily in TSCI, total proteins, albumins, specific immune cells (blood) or some biomarkers in urine were also observed to change after trauma in a time-dependent manner.^{6–8} In this study, the main aim was to assess and directly compare in a relatively homogenous community (Trois-Rivières City, Quebec, Canada) time-dependent changes of biochemical profiles (blood, serum and urine) between TSCI and NTSCI patients. This article is the second in a series of three studies aimed to describe the epidemiological, clinical, functional (first article) and pharmacological (third article) characteristics associated with TSCI and NTSCI patients.

Correspondence: Dr PA Guertin, Laval University Medical Center (CHUL), Neuroscience Unit, RC-9800, 2705 Laurier boulevard, Quebec City, Quebec, Canada G1V 4G2.

E-mail: Pierre.Guertin@crchul.ulaval.ca

Received 4 December 2009; revised 18 March 2010; accepted 19 March 2010; published online 11 May 2010

Materials and methods

This protocol was approved by the institution in which medical records came from (Interval Rehabilitation Center, Trois-Rivieres, QC, Canada) and by an independent ethics committee (International Review Board Services, Aurora, ON, Canada). We studied data from male and female patients ($n=175$) from the Interval Rehabilitation Center that have been SCI traumatically (94 patients) or non-traumatically (81 patients) for at least 1 year and typically less than 10 years. Their complete medical records at the Rehabilitation Center were thoroughly examined to pre-select commonly reported sets of characteristics. Patients were functionally classified using the standard American Spinal Cord Association (ASIA) classification. Biochemical data from blood (erythrocyte or red blood cell (RBC), Ht, Hb, platelets, leukocyte, lymphocyte and neutrophil levels), serum (protein, albumin, creatinine, uric acid, glucose, sodium, potassium, chloride, cholesterol, triglyceride, HDL-C, LDL-C, cholesterol/HDL-C ratio) and urine (levels of specific gravity, blood, leukocyte, nitrite, pH, protein) presented in this study are expressed as arithmetic sums (incidences) or means $\pm$ s.e. analyzed with Student's *t*-tests (Prism V5, Graph Pad Software, La Jolla, CA, USA). It should be noted that data from all medical records were used, although all characteristics and biomarkers assessed were not generally found in every single medical record.

Results

Preliminary data

Results from the first article of this series of three papers revealed in these patients the existence of clear differences in age, gender, extent and level of injury and secondary complications between groups (TSCI vs NTSCI patients). For instance, essentially no completely injured patients were found among the NTSCI group, whereas completely injured patients constituted 37.8% of all TSCI patients. Furthermore, we observed that the incidence of neurogenic bladder, neurogenic bowel, urinary tract infection and pressure ulcers was significantly greater in TSCI than NTSCI patients, whereas neuropathic pain was equally found in patients from both groups.

Red blood cells

Red blood cell analyses clearly showed that erythrocyte (RBC) counts progressively increased over time after SCI (Figure 1). Levels ranging between 3.8 and 4.1×10^{12} per liter detected in acute and early chronic patients (0–1 month post-trauma or post-acute care hospitalization) were observed to progressively increase ($P<0.01$) by 11% (4.4×10^{12} per liter) in late chronic SCI patients (combining both groups of TSIs and NTSCIs; Figure 1a). Comparable augmentations ($P<0.001$ and $P<0.05$) were also observed with Hb (15% increase) and Ht (8% increase) levels in late chronic compared with early chronic SCI patients (Figures 1c–e), whereas platelet levels did not change over time (Figure 1g). Interestingly, when comparing separately TSCI and NTSCI patients, results showed that only NTSCI patients were

Figure 1 Time-dependent changes of red blood cells in spinal cord-injured (SCI) patients and differences between non-traumatic spinal cord-injured (NTSCI) and traumatic spinal cord-injured (TSCI) patients. *Statistically significant differences over time within-group (*) or at fixed time between groups (+).

observed to display significantly ($P<0.05$) increased levels of RBCs and Hts in late chronic patients compared with those at earlier stages (Figures 1b and f). Although these characteristics displayed higher values also in TSCI patients, many of them did not change significantly ($P>0.05$) over time in TSCI patients (that is, except for Hb values that significantly ($P<0.001$) increased over time in TSCI patients, Figure 1d).

White blood cells

The results showed also clear changes in leukocyte counts (Figure 2). The later significantly ($P<0.05$) decreased (19% decrease) over time in mid-chronic and late-chronic SCI patients (combining both data from NTSCI and TSCI

Figure 2 Time-dependent changes of white blood cells in spinal cord-injured (SCI) patients and differences between non-traumatic spinal cord-injured (NTSCI) and traumatic spinal cord-injured (TSCI) patients. *Statistically significant differences over time within-group (*) or between groups (†).

patients) compared with early chronic subjects (Figure 2a). Specifically, lymphocytes (expressed as percentages of total leukocytes) significantly increased (16% increase, $P < 0.05$), whereas neutrophils proportionally decreased, although this failed to reach significance (5% decrease, $P > 0.05$). This apparent discrepancy (that is, decreased total leukocytes and increased neutrophils) may be caused by altered levels in other types of leukocytes (not generally reported in the medical records studied here). When comparing TSCI and NTSCI patients, results revealed a near 20% decrease of leukocytes over time in each group, although not significant statistically ($P > 0.05$). However, the large increase in lymphocyte levels in both groups mentioned earlier was revealed with this comparative analysis to be entirely attributable to a large augmentation (a near twofold increase, $P < 0.05$) only in NTSCI patients (late chronic vs earlier stages), whereas neutrophil levels were significantly ($P < 0.05$) lower in NTSCI compared with TSCI patients (only at the late chronic stage, Figure 2f).

Serum lipid profile

In SCI patients (both groups combined), cholesterol, HDL-C and LDL-C levels were all significantly increased over time

Figure 3 Time-dependent changes in serum lipid levels in spinal cord-injured (SCI) patients and differences between non-traumatic spinal cord-injured (NTSCI) and traumatic spinal cord-injured (TSCI) patients. *Statistically significant differences over time within-group (*). ** $P < 0.01$.

(Figure 3). Specifically, cholesterol displayed a 20% increase ($P < 0.05$) in mid-chronic and late chronic SCI patients compared with early chronic subjects (Figure 3a). The HDL-C and LDL-C levels also increased over time with statistical significance ($P < 0.01$), respectively, in late chronic

Table 1 Time-dependent changes of other serum markers in SCI patients and differences between NTSCI and TSCI patients

	0–1 month			1–12 month			> 12 month		
	SCI	TSCI	NTSCI	SCI	TSCI	NTSCI	SCI	TSCI	NTSCI
Protein (g l ⁻¹)	59.5 ± 1.5	60.7 ± 3.0	58.7 ± 1.7	62.2 ± 1.6 [§]	64.7 ± 2.2	61.4 ± 1.9	68.4 ± 2.4	66.6 ± 2.6	69.8 ± 3.9
Albumin (g l ⁻¹)	31.2 ± 1.2	33.0 ± 2.2	30.0 ± 1.3	33.0 ± 1.0	36.9 ± 1.8 ^{††}	31.2 ± 0.9 [§]	35.2 ± 1.9	33.5 ± 2.8	36.6 ± 2.6
Creatinine (μmol l ⁻¹)	77.0 ± 6.2	73.0 ± 10.3	81.5 ± 6.6*	95.6 ± 9.1	68.2 ± 5.7 ^{††}	117.8 ± 14.1 [§]	65.1 ± 3.7	67.8 ± 5.0	58.6 ± 3.4
Urea (mmol l ⁻¹)	5.8 ± 0.5	4.8 ± 0.4	6.7 ± 0.9	7.4 ± 0.9	6.2 ± 1.4	8.1 ± 1.2 [§]	4.8 ± 0.7	5.9 ± 1.3	3.7 ± 0.4
Glucose (mmol l ⁻¹)	5.8 ± 0.3	5.2 ± 0.3	6.1 ± 0.4	5.2 ± 0.2	5.1 ± 0.3	5.3 ± 0.2	6.3 ± 0.7	5.6 ± 0.4	7.3 ± 1.5
Sodium (mmol l ⁻¹)	136.3 ± 1.1	137.4 ± 0.8	135.3 ± 2.0	138.4 ± 0.6	137.6 ± 1.2	138.9 ± 0.6	140.0 ± 0.6	139.7 ± 0.6	140.5 ± 1.4
Potassium (mmol l ⁻¹)	4.1 ± 0.1*	4.2 ± 0.1	4.1 ± 0.1*	4.4 ± 0.1	4.3 ± 0.2	4.5 ± 0.1	4.3 ± 0.1	4.3 ± 0.2	4.3 ± 0.2
Chloride (mmol l ⁻¹)	99.1 ± 1.7*	101.0 ± 1.0	98.1 ± 2.5*	103.6 ± 1.1	99.4 ± 1.3	105.0 ± 1.2	101.7 ± 0.6	101.4 ± 1.0	102.1 ± 0.6

Abbreviations: NTSCI, non-traumatic spinal cord injured; SCI, spinal cord injured; TSCI, traumatic spinal cord injured.

*Statistically significant differences over time within-group (*for 0–1 month / 1–12 month, for 0–1 month/> 12 month and §for 1–12 month/> 12 month) or between groups (†).

Table 2 Time-dependent changes in urine biomarkers in SCI patients and differences between NTSCI and TSCI patients

	0–1 month			1–12 month			> 12 month		
	SCI	TSCI	NTSCI	SCI	TSCI	NTSCI	SCI	TSCI	NTSCI
Specific Gravity	1.019 ± 0.001	1.019 ± 0.003	1.019 ± 0.002	1.017 ± 0.003	1.023 ± 0.004	1.019 ± 0.006	1.017 ± 0.002	1.017 ± 0.002	1.019 ± 0.004
Blood	0.81 ± 0.22	0.48 ± 0.27	0.99 ± 0.30	1.17 ± 0.29	0.69 ± 0.28	1.53 ± 0.44	0.53 ± 0.15	0.61 ± 0.20	0.36 ± 0.17
Leukocytes	1.29 ± 0.24	0.37 ± 0.20	1.86 ± 0.30 ^{††}	1.06 ± 0.29	0.54 ± 0.34 [§]	1.45 ± 0.42	1.59 ± 0.27	1.54 ± 0.29	1.73 ± 0.68
Nitrite	0.20 ± 0.06	0.08 ± 0.06	0.27 ± 0.09	0.26 ± 0.09	0.40 ± 0.16	0.14 ± 0.09	0.45 ± 0.11	0.50 ± 0.13	0.31 ± 0.18
pH	5.95 ± 0.15	6.22 ± 0.29	5.80 ± 0.17	6.17 ± 0.14	6.08 ± 0.27	6.25 ± 0.15	6.10 ± 0.16	6.25 ± 0.20	5.83 ± 0.28
Protein (g l ⁻¹)	0.08 ± 0.05	0.14 ± 0.11	0.05 ± 0.04	0.20 ± 0.09	0.14 ± 0.11	0.24 ± 0.14	0.24 ± 0.09	0.33 ± 0.13	0.06 ± 0.04
Urobilinogen (μmol l ⁻¹)	7.73 ± 1.33**	8.95 ± 2.01	7.04 ± 1.77	3.87 ± 0.67	3.20 ± 0.00	4.27 ± 1.07	3.84 ± 1.0	3.00 ± 1.07	5.19 ± 1.99

Abbreviations: NTSCI, non-traumatic spinal cord injured; SCI, spinal cord injured; TSCI, traumatic spinal cord injured.

Statistically significant differences over time within-group (*for 0–1 month/1–12 month, for 0–1 month/> 12 month and §for 1–12 month/> 12 month) or between groups (†).

or mid-chronic SCI patients compared with earlier stages (Figures 3e and g). However, triglyceride levels did not significantly ($P > 0.05$) change over time (Figure 3c), whereas C/HDL-C ratio values decreased ($P < 0.01$) in late chronic SCI patients compared with mid-chronic subjects (Figure 3i). When specifically comparing both groups, results revealed that the cholesterol and LDL-C augmentations mentioned earlier were found ($P < 0.05$) only in NTSCI patients (Figures 3b and h), whereas lower ($P < 0.05$) C/HDL-C ratio values were detected only in TSCI patients (late chronic vs mid-chronic subjects, Figure 3j).

Other serum biomarkers

In brief, protein, potassium and chloride levels were significantly increased over time, whereas creatinine level progressively decreased in SCI patients (with both groups combined; Table 1). Specifically, serum protein levels increased ($P < 0.01$) by 15% in late chronic SCI patients compared with early chronic SCI patients. Potassium and chloride levels significantly increased by 3–4% in mid-chronic SCI patients compared with early chronic SCI patients. In contrast, albumin, uric acid, glucose and sodium levels did not significantly ($P > 0.05$) change over time (Table 1). However, when comparing both groups, results revealed differential effects. For instance, protein, albumin, potassium and chloride levels were increased ($P < 0.05$) over time only in NTSCI patients (either late or mid-chronic

patients vs early chronic patients), whereas creatinine and uric acid levels decreased ($P < 0.05$) again only in NTSCI patients (that is, late chronic vs mid-chronic patients, Table 1).

Urine biomarkers

Although several serum biomarkers were found to change over time (specifically in NTSCI), urine biomarkers were shown to remain relatively stable. For instance, specific gravity, blood, leukocyte, pH and protein levels did not significantly change over time in SCI patients (both groups combined; Table 2). Only nitrite and urobilinogen levels were shown to significantly ($P < 0.05$) increase (twofold) and decrease (twofold), respectively. When comparing both groups, results revealed that the increase in nitrite levels occurred only in TSCI patients, whereas urobilinogen levels were similarly decreased in both groups although this decrease was significant ($P < 0.05$) only in TSCI patients (Table 2).

Discussion

This study, to the best of our knowledge, is the first to report the existence of clear differences over time in biochemical profiles of TSCI vs NTSCI patients. In brief, results showed that red blood constituents generally increased over time in SCI patients. In contrast, leukocytes generally decreased over

time in both groups, although significant lymphocyte level increases (twofold) were observed only in late chronic NTSCI patients. Cholesterol, LDL-C, protein, albumin, potassium and chloride levels also increased over time specifically in NTSCI subjects (late chronics vs earlier stages), whereas creatinine and uric acid levels specifically decreased in late chronic NTSCI individuals. In contrast, urine biomarkers, such as nitrite and urobilinogen, specifically increased and decreased, respectively, over time only in TSCI patients (late versus early chronics).

Data from the literature has already shown that mild anemia, including abnormally low erythrocyte levels, which do not depend upon age or completeness of injury, can be found after SCI.⁹ This is in apparent contrast with our results that essentially show increasing Ht, Hb and erythrocyte (RBC) levels in late vs early chronic patients (significant only in NTSCI patient). However, mild anemia has been specifically reported in acute and early chronic TSCI patients,^{7,9,10} whereas a study by Lipetz *et al.*⁸ clearly demonstrated a return to near-normal levels over time (in late vs early chronic TSCI). This is thus in line with our results showing abnormally low levels of erythrocytes in early chronic SCI patients with 3.9×10^{12} per liter (Figure 1a), given that normal levels typically range between 4.5 and 5.9×10^{12} per liter.^{11,12} In other words, although we reported augmentations over time, the levels of RBC, Hb and Ht were simply shown to return to near normal levels (4.5 – 11×10^9 per liter, 135 – 175 g l^{-1} , 0.41 – 0.53 , respectively) in late chronic SCI patients (>1 year after acute care hospitalization). In turn, platelets were not observed in this study to change over time. They remained within a normal range (140 – 400×10^9 per liter), which is in contrast, to some extent, with results found elsewhere in acute and early chronic tetraplegic TSCI patients showing abnormally low platelet levels.¹³ Reasons underlying mild anemia in early chronic SCI patients are unclear but may be associated with surgery, urinary tract infections and bed sores.^{7,14} To the best of our knowledge, this is the first time that significant RBC changes over time are being reported in NTSCI patients.

Regarding white blood cells, it has been generally reported in the literature that leukocytes normally increase in the first few days post-trauma (for example, 10 – 16×10^9 per liter).^{7,15} In this study, we report data supporting the idea of a relatively rapid return to normal levels over time because, in mid-chronic SCI patients, leukocyte counts already diminished to levels ranging between 7 and 8×10^9 per liter, which are well within normal levels (4.5 – 11×10^9 per liter).^{11,12} However, it is of particular interest in this study to have shown, to the best of our knowledge, for the first time that comparable changes (and even larger since significant) occur also in NTSCI patients—that is, lymphocyte levels that initially decrease in early stages and return to normal levels in late chronic NTSCI patients (compared with acute and early chronic subjects) and thus that return to normal levels (that is, neutrophil and lymphocyte normal levels are 42 – 75% and 20 – 50% , respectively).^{11,12} Such a change in leukocyte and lymphocyte levels (increase and decrease, respectively) has also been reported in TSCI patients that suffer of bed sores,¹³ whereas a progressive return to

normal values has been shown in TSCI patients 6 months post-trauma.¹⁶

Dyslipidemia is generally known to progressively occur in TSCI patients (see companion paper no.1). Relatively low HDL-C levels that do not depend on unbalanced total cholesterol levels or age have indeed been reported in chronic tetraplegics.¹⁷ This may be caused by reduced physical activity (or physical inactivity) associated with a decrease in catecholamine levels.^{18,19} Differences associated with injury level, including higher very LDL-C and triglycerides, as well as higher total cholesterol and LDL-C levels have been reported in late chronic TSCI patients.²⁰ This study is, to the best of our knowledge, the first to report increased levels (above normal) of cholesterol in NTSCI patients. Indeed, levels ranging between 5 and 6 mmol l^{-1} , which are in the upper range of normal values (3.4 – 6.2 mmol l^{-1}) were found in late chronic NTSCI patients, whereas rather normal levels (that is, just above 4 mmol l^{-1}) were found in TSCI patients (Figure 3b).^{11,12} We also found that triglyceride levels in both groups (between 2 and 3 mmol l^{-1} particularly in late chronics) were above normal levels (typically between 0.4 and 1.6 mmol l^{-1})^{11,12} and remained unchanged over time (Figure 3d). Surprisingly, HDL-C and LDL-C levels were reported in both groups to remain within normal ranges (0.9 – 1.55 mmol l^{-1} and 2.1 – 4.1 mmol l^{-1} respectively) although LDL-C levels increased over time only in NTSCI patients (Figure 3h). This is in contrast with data generally reported in the literature (that is, in TSCI patients) reporting abnormally low HDL-C and high LDL-C level.^{4,17,20} This said, improved dyslipidemia-related marker profiles may be associated with ameliorated physical activity levels over time as proposed elsewhere.^{18,19} Given that patients from the Interval rehabilitation center are encouraged to remain physically active, this may possibly explain rather normal HDL-C and LDL-C values in both groups of patients compared with data normally found in the literature (at least for TSCI subjects).

We also found that protein, albumin, potassium and chloride levels were increased over time specifically in NTSCI subjects. Protein and albumin levels although elevated (69 and 36 g l^{-1}) in late chronic NTSCI patients compared with early chronics remained within a normal range (62 – 81 g l^{-1} and 32 – 46 g l^{-1} , respectively).^{11,12} Similar results were found with potassium and chloride, which remained within normal values (3.5 – 5.1 mmol l^{-1} and 98 – 107 mmol l^{-1}) despite higher levels detected in mid-chronic versus early chronic NTSCI patients. All other parameters examined here such as uric acid, glucose and sodium remained relatively unchanged and within normal values excepted for creatinine, which decreased ($\sim 60 \text{ mmol l}^{-1}$) significantly below normal levels (80 – 115 mmol l^{-1}) in late chronic NTSCI patients. It has been shown in TSCI patients that renal impairment is typically associated with a concomitant increase of both serum protein and creatinine levels²¹ (as shown here), strongly suggesting that greater renal problems were experienced over time in late chronic patients than in early chronic patients. Again, this is, to the best of our knowledge, the first time that such changes are studied and found to be significant in NTSCI patients.

An abnormally high nitrite level, as observed in this study, specifically in TSCI patients (late versus early chronics) is a well-known indicator of urinary tract infections, suggesting that significant urinary tract infection cases were found in this group. Finally, although urobilinogen levels were significantly lower in late vs early chronic TSCI, they remained within normal values ($<16 \mu\text{mol l}^{-1}$), suggesting normal red blood profile and liver function.

Conclusion

This study strongly supports the idea that differences in biochemical profile may exist between TSCI vs NTSCI or early vs late chronic patients. However, although many parameters and biomarkers were found to change over time, most remained within or returned towards normal levels within 1 year after injury or diagnosis.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgements

We thank the Interval Rehabilitation Center for its collaboration and devoted work in retrieving the corresponding medical files and, occasionally, some missing information. We also thank Nordic Life Science Pipeline and NeuroSpina Therapeutics that supported this 3-year study.

References

- Vidal J, Javierre C, Curià FJ, Garrido E, Lizarraga MA, Segura R. Long-term evolution of blood lipid profiles and glycemic index in patients after spinal cord injury. *Spinal Cord* 2003; **41**: 178–181.
- Scivoletto G, Fuoco U, Morganti B, Cosentino E, Molinari M. Pressure sores and blood and serum dysmetabolism in spinal cord injury patients. *Spinal Cord* 2004; **42**: 473–476.
- Cardús D, Ribas-Cardús E, McTaggart WG. Lipid profiles in spinal cord injury. *Paraplegia* 1992; **30**: 775–782.
- Bauman WA, Zhang RL, Spungen AM. Provocative stimulation of growth hormone: a monozygotic twin study discordant for spinal cord injury. *J Spinal Cord Med* 2007; **30**: 467–472.
- Kemp BJ, Spungen AM, Adkins RH, Krause JS, Bauman WA. The relationships among serum lipid levels, adiposity, and depressive symptomatology in persons aging with spinal cord injury. *J Spinal Cord Med* 2000; **23**: 216–220.
- Zhong YG, Levy E, Bauman WA. The relationships among serum uric acid, plasma insulin, and serum lipoprotein levels in subjects with spinal cord injury. *Horm Metab Res* 1995; **27**: 283–286.
- Gurcay E, Bal A, Gurcay AG, Cakci A. Evaluation of blood and serum markers in spinal cord injured patients with pressure sores. *Saudi Med J* 2009; **30**: 413–417.
- Lipetz JS, Kirshblum SC, O'Connor KC, Voorman SJ, Johnston MV. Anemia and serum protein deficiencies in patients with traumatic spinal cord injury. *J Spinal Cord Med* 1997; **20**: 335–340.
- Perkash A, Brown M. Anemia in patients with traumatic spinal cord injury. *J Am Paraplegia Soc* 1986; **9**: 10–15.
- Huang CT, DeVivo MJ, Stover SL. Anemia in acute phase of spinal cord injury. *Arch Phys Med Rehabil* 1990; **71**: 3–7.
- Dore D. *Biochimie Clinique* 1994 Eds, Editions Le Griffon d'Argile et Editions Maloine: Paris.
- US National Library of Medicine and the National Institutes of Health. Complete Blood Count in Medline Plus. www.nlm.nih.gov/medlineplus/ency/article/003642.htm.
- Furlan JC, Krassioukov AV, Fehlings MG. Hematologic abnormalities within the first week after acute isolated traumatic cervical spinal cord injury: a case-control cohort study. *Spine* 2006; **31**: 2674–2683.
- Hirsch GH, Menard MR, Anton HA. Anemia after traumatic spinal cord injury. *Arch Phys Med Rehabil* 1991; **72**: 195–201.
- Katoh S, Ikata T, Tsubo M, Hamada Y, el Masry WS. Possible implication of leukocytes in secondary pathological changes after spinal cord injury. *Injury* 1997; **28**: 215–217.
- Cruse JM, Lewis RE, Bishop GR, Kliesch WF, Gaitan E. Neuro-endocrine-immune interactions associated with loss and restoration of immune system function in spinal cord injury and stroke patients. *Immunol Res* 1992; **11**: 104–116.
- Shetty KR, Sutton CH, Rudman IW, Rudman D. Lipid and lipoprotein abnormalities in young quadriplegic men. *Am J Med Sci* 1992; **303**: 213–216.
- Arner P, Wahrenberg H, Lönnqvist F, Angelin B. Adipocyte beta-adrenoceptor sensitivity influences plasma lipid levels. *Arterioscler Thromb* 1993; **13**: 967–972.
- Dearwater SR, LaPorte RE, Robertson RJ, Brenes G, Adams LL, Becker D. Activity in the spinal cord-injured patient: an epidemiologic analysis of metabolic parameters. *Med Sci Sports Exerc* 1986; **18**: 541–544.
- Schmid A, Halle M, Stützle C, König D, Baumstark MW, Storch MJ et al. Lipoproteins and free plasma catecholamines in spinal cord injured men with different injury levels. *Clin Physiol* 2000; **20**: 304–310.
- Wall BM, Huch KM, Mangold TA, Steere EL, Cooke CR. Risk factors for development of proteinuria in chronic spinal cord injury. *Am J Kidney Dis* 1999; **33**: 899–903.