RR Variability In Spinal Cord Injured Patients

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Citation

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Abstract

Patients with spinal cord injury are prone to cardiovascular dysfunction and an increased risk of cardiovascular disease. The purpose of this study was to establish RR variability values for normal persons and compare them with values found in patients with spinal cord injury and to determine how interruption of connections between the central nervous system and spinal sympathetic motor neurons affects autonomic cardiovascular control. To determine values for RR variability, we recruited a sample of 38 healthy persons of 17 to 60 years old and 20 persons with spinal cord injury. In this study, R-R series signals were recorded in three different modes: supine, sitting and five seconds deep respiration. At a time, in each mode 150 seconds R-R interval data was acquired. We defined and analyzed six indices: SuB, StB, DbB, DOS, DRS and ROR. We performed traditional power spectral analyses to quantify total power, very-low-frequency (VLF) power, low-frequency (LF) power, high-frequency (HF) power, and the ratio of LF to HF power. It was observed that most of the indices were significantly and substantially altered in spinal cord injured persons. The paper presents the differences in RR variability between normal & SCI persons.

INTRODUCTION

Spinal cord injuries at the thoracic level and below result in paraplegia. Paraplegia describes complete or incomplete paralysis affecting the legs and possibly also the trunk, but not the arms. Cervical i.e. neck injuries usually result in four limb paralysis. This is referred to as Tetraplegia or Quadriplegia [1, 2]. Destruction of a small portion of the spinal cord produces profound motor and sensory changes below the level of the lesion. The autonomic nervous system makes up a major part of the body's control system for normal functions, mediating all the unconscious activities of the viscera and organs. Spinal Cord Injury may show symptoms and signs that the autonomic system has been affected by the injury. Studies of cardiovascular abnormalities after SCI show that of patients with severe cervical injuries (American Spinal Injury Association [ASIA] A and B), up to 100% develop bradycardia, 68% are hypotensive and 16% have primary cardiac arrest. Of those with milder cervical injuries (ASIA C and D), 35-71% develop persistent bradycardia. Patients in this group rarely have primary cardiac arrest. Patients with thoracolumbar injuries have rate of 13-35% of bradycardia with no other cardiovascular problems [21].

R-R VARIABILITY

The R-R variability (RRV) or Heart rate variability (HRV) is a non-invasive index of the neural control of the heart. The last three decades have witnessed the recognition of a significant relationship between the autonomic nervous system and cardiovascular mortality, including sudden cardiac death [3,4,5,6,7,8,9,10,11,12,13,14,15,16]. Experimental evidence for an association between propensity for lethal arrhythmias and signs of either increased sympathetic or reduced vagal activity has spurred efforts for the development of quantitative markers of autonomic activity (Task Force, 1996). Heart rate variability (HRV) represents one of the most promising such markers. Autonomic markers such as HRV are receiving increasing attention for the identification of patients at high risk. In HRV analysis either the heart rate as a function of time or the intervals between successive QRS complexes need to be determined. There are two methods of analysis of HRV data: time-domain analysis and frequency-domain analysis. In either method, the inter-beat intervals should be properly calculated and all abnormal heartbeats and artifacts removed from consideration [3,4,5,6,7,8,9,10,11,12,13,14,15,16].

MATERIALS AND METHODS

The purpose of this study was to establish RR variability values for normal persons and compare them with values found in patients with spinal cord injury. To determine values for RR variability, we recruited a sample of 38

healthy persons of 17 to 60 years old and 20 persons with spinal cord injury as described in Table 1. In this study, R-R intervals were recorded in three different modes or positions: supine, sitting and five seconds deep respiration. At a time, in each mode 150 seconds R-R interval data was acquired.

Figure 1

Table 1: Participant Characteristics

Characteristics	Normal	SCI
Total Number	38	20
Age	17 to 60 Years	22 to 67 Years
Gender	34 males, 12 females	18 males, 2 females

All experiments were performed in the afternoon between 2.00 pm to 7.00 pm, at least 2 hours after a lunch in a quiet environmentally controlled recording room. The subjects were asked to refrain from heavy exercise and smoking for at least 24 hours before the tests. All subjects were free from any known disease based on medical history and physical examination at the time of the study. After entering in to the recording room, each participant was transferred onto a table. Then, the cardiosport belt was fixed around the chest to acquire and transmit electromagnetic pulses that represent 'R' waves. The subject was asked to relax for 10 minutes to achieve steady-state resting condition, before the start of data collection. The testing protocol consisted of a 2.5 minutes supine-mode recording, a 2.5-minutes sitting-mode recording, a 10 minutes supine rest and 2.5 minutes deep breathing recording.

We used a cardiosport pulse transmitter belt to detect and transmit 'R' waves. It is lightweight, waterproof, comfortable, and accurate [16, 17]. The belt is to be worn around the chest that sends an electromagnetic signal every time when 'R' peak is detected. The cardiopulse receiver designed and developed for this purpose was used to acquire 'R' peaks. The transmission signal is 5 kHz frequency bursts that last for 35 milliseconds. The RR interval times are obtained by measuring the time between the start of one 5 kHz burst and the next 5 kHz burst. This is done by generating a sharp pulse for each event. The signal is fed to laptop computer via parallel port ADC card (Picotech) and displayed using Picoscope software [18]. Irrelevant pulses were edited and processed to produce R-R series rhythmogram. Digital signal processing software DADiSP [19] and Ortoscience [20] softwares were employed to process acquired signal. We defined and analyzed following six indices to present our results

SuB: Sympathetic to Para-Sympathetic Balance Index – Supine

Ratio of spectral power in the low frequency range (0.04 – 0.15 Hz) to the spectral power in the high frequency range (0.15 - 0.4 Hz) during supine mode.

SuB = SPL(Su) / SPH(Su) (1)

StB: Sympathetic to Para-Sympathetic Balance Index – Sitting

Ratio of spectral power in the low frequency range (0.04 – 0.15 Hz) to the spectral power in the high frequency range (0.15 - 0.4 Hz) during sitting mode.

StB = SPL(St) / SPH(St) (2)

DbB: Sympathetic to Para-Sympathetic Balance Index– Deep Breathing

Ratio of spectral power in the low frequency range (0.04 – 0.15 Hz) to the spectral power in the high frequency range (0.15 - 0.4 Hz) during deep respiration mode.

DbB = SPL(Db) /SPH(Db) (3)

DOS: Dynamic Orthostatic Stress Index

DOS = (StB-SuB)/SuB) (4)

DRS: Dynamic Respiratory Stress Index

DRS = (1/DbB-1/SuB)/(1/SuB) (5)

ROR: Ratio of Balance during Sitting to Balance during Deep Respiration

DRS = StB/DbB (6)

RESULTS

We defined and calculated frequency domain indices for normal and SCI subjects. Then, we conducted the nonparametric test, Mann Whitney U-Wilcoxon Rank W test for statistical analysis of the measured indices between normal and SCI groups. The test results give the effectiveness of measured indices to differentiate the normal and SCI subjects. The criterion for significance was a p-value <0.05. The calculated indices for various modes along with their p-values are shown in Table2.

Figure 2

Table 2: List of indices and their values for normal and SCI groups

Autonomic Index	Mean Normal	SD	Mean SCI	SD	P-Value
SuB: Sympathetic to Para-Sympathetic Balance Index – Supine, *SPL(Su) / SPH(Su)*	**1.650**	0.390	**3.079**	1.493	**<0.001**
StB: Sympathetic to Para-Sympathetic Balance Index – Sitting, *SPL(St) / SPH(St)*	5.040	1.714	4.577	1.775	0.453
DbB: Sympathetic to Para-Sympathetic Balance Index – Deep Breathing, *SPL(Db) /SPH(Db)*	**0.350**	0.153	**1.756**	0.942	**<0.001**
DOS: Dynamic Orthostatic Stress Index, (StB-SuB)/SuB	**2.191**	1.257	**0.627**	0.657	**<0.001**
DRS: Dynamic Respiratory Stress Index(1/DpB-1/SuB)/(1/SuB)	**4.764**	3.272	**0.170**	0.223	**<0.001**
ROR: Ratio of Balance during Sitting to Balance during Deep Respiration, StB/DbB	**14.41**	11.696	**3.210**	1.631	**<0.001**

Figure 3

Figure 1: Spectral analysis of normal and spinal cord injured subjects during supine mode

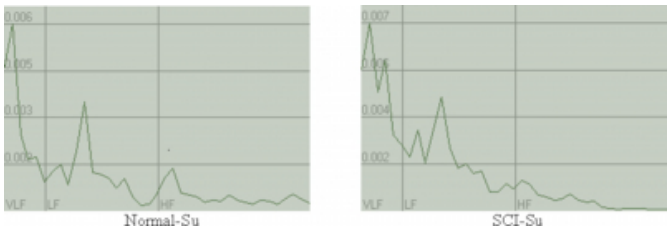


Figure 4

Figure 2: Spectral analysis of normal and spinal cord injured subjects during sitting mode

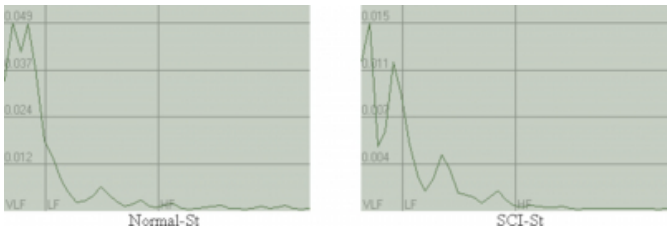


Figure 5

Figure 3: Spectral analysis of normal and spinal cord injured subjects during deep breathing

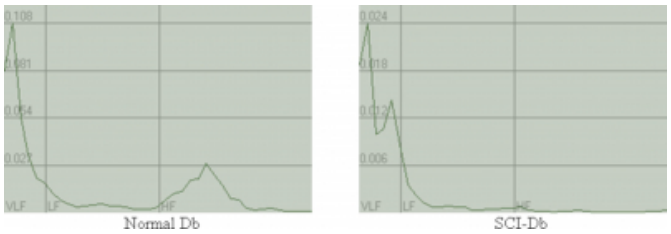


Figure 6

Figure 4: Relation between SuB, StB and DbB indices for normal and spinal cord injured subjects

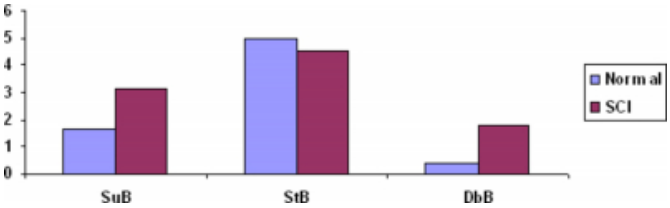
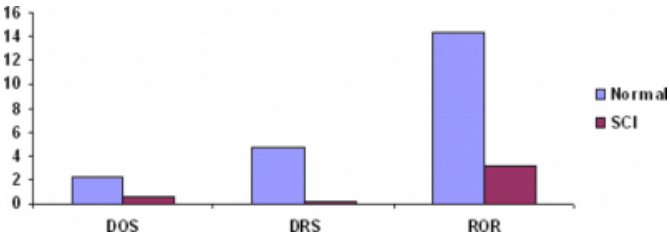


Figure 7

Figure 5: Relation between DOS, DRS and ROR indices for normal and spinal cord injured subjects



Typical power spectral density curves during three modes for normal and spinal cord injured subjects are shown in fig.1, 2 and 3. Graphical relations between various indices for normal and SCI subjects are shown in Fig. 4 and 5. Out of 6 indices calculated, 5 indices have a p-value less than 0.05. The significance is clearly visible in most of the graphs. It has been observed that spinal cord injured subjects have very high muscle tone resulting in to prominent sympathetic activity and poor vagal activity at all conditions compared to normal subjects which is a poor sign of cardiac health. SuB index shows significant difference in index values. Although, StB index values are comparable in both, actual variance is very low. DbB index is very much affected; for normal subjects it is 0.35, whereas for SCIs it is more than 1.7. This clearly indicates roll of sympathetic activity in SCI. DOS index shows significant reduction from 2.19 to 0.62 in SCIs. This is indicative of damage to the sympathetic and parasympathetic system. A similar trend is indicated in DRS index showing reduction in index value. This index gives the effectiveness of vagal control on R-R interval or heart rate and is considerably reduced from 4.76 to 0.17. Thus, the Ratio of Balance during Sitting to Balance during Deep Respiration (ROR) is also severally affected. For normal it is 14.41, whereas for SCIs it is only 3.2. This clearly indicates, how individuals with spinal cord injury are prone to cardiovascular dysfunction and an increased risk of cardiovascular disease. The analysis shows that SCI are not able to withstand orthostatic stress and they have poor sympathetic to vagal balance. Graphical images of all these

indices present the typical variability picture of SCI patients, which is significantly different from normal subjects.

CONCLUSION

This study establishes normal values for frequency-domain measures of RR variability for normal and spinal cord injured subjects. In our current study, we observed that the measured indices clearly show typical variability picture of SCI patients, which is significantly different from normal subjects. It is confirmed that SCI patients have very poor RR variability, they are not able to withstand orthostatic stress and they have poor sympathetic to vagal balance. In conclusion, the SCI community presents a different picture of RR variability.

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