Comparison of Cervical Proprioception and Simple Reaction Time in Subjects with Brachial Plexopathies and Healthy Adults

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Abstract: ***Background**: Brachial Plexus Injuries are devastating life altering injuries occurring with increasing frequency in young adults. The factors causing BPI includes both traumatic (most common) and non - traumatic. **Objectives**: To compare cervical proprioception using cervico - cephalic relocation test and Simple reaction time using Deary - Liewald reaction time task in subjects with Brachial Plexopathies and age matched Healthy Adults. **Methodology**: A total of 60 participants screened according to the inclusion and exclusion criteria were conveniently allocated into one of the two groups namely, group A consisting the Brachial Plexus patients and group B consisting age matched healthy adults to assess Cervical proprioception and Simple reaction time. Cervical Proprioception in degrees (x^0) and Simple Reaction Time measured in milliseconds (ms) were measured. **Results**: Group A (Brachial plexus patients) showed significantly higher values in the mean error angle for right rotation of Cervical Proprioception (Group A - 7.307; Group B - 4.587; $p<0.0001$). Group A showed significantly higher values in the mean error angle for left rotation of Cervical Proprioception (Group A - 8.153, Group B - 4.299; $p<0.0001$). Group A showed significantly delayed Simple Reaction Time (Group A – 386.01, Group B – 288; $p<0.0001$). **Conclusion**: 1) Cervical Proprioception showed a significant affection in mean error angle on right as well as left rotation in Brachial Plexus injury patients when compared with age matched Healthy Adults. 2) Simple Reaction Time was significantly delayed in Brachial Plexus injury patients when compared with age matched Healthy Adults.***

Keywords: Brachial Plexus Injury, cervical proprioception, simple reaction time, afferent - efferent loop, sensorimotor pathway

1. Introduction

Brachial plexus is the complex network of nerves, which innervates the upper extremity. (1) Spinal nerves are formed by the union of ventral and dorsal spinal nerve roots as they emerge through the intervertebral foramina. (2) The formation of Brachial plexus is in the posterior cervical triangle by the union of ventral rami of 5th, 6th, 7th, and 8th cervical nerve roots and 1st thoracic nerve root. (1) Upper trunk is formed by C5 and C6 roots, the C8 and T1 roots merge to form the lower trunk. C7 becomes the middle trunk. (3) With respect to the dorsal root ganglion, lesions or injuries to brachial plexus are classified based on their location: a preganglionic injury is proximal to the dorsal root ganglion and a postganglionic injury is distal to the dorsal root ganglion. (4)

There is a significant higher prevalence of traumatic BPI in male gender; ages between 15 and 25 years old. (3). Traumatic lesions to brachial plexus in the adult population are devastating life altering injuries occurring with increasing frequency. (4) Symptoms of brachial plexopathies include transient period of burning, disabling neuropathic pain, stinging sensation, and loss of muscle power throughout the involved upper limb. (6)

There are several mechanisms which could cause brachial plexus injury but the most common and prevalent is a force that causes lateral flexion of cervical spine and concomitant shoulder depression to contralateral side (Burner or stinger injury). (6) Time period for surgery or intervention is dependent on the mechanism and type of injury. (4)

Proprioception is the ability to sense bodily movement position, which includes position sense also known as joint position sense and movement sense known as kinesthesia. Dysfunction in the cervical proprioceptive sensation is primarily affected by impairment in cervical muscles, joints, or capsules and, secondarily, by alteration in afferent proprioceptive tuning and integration. (9)

Cervical sensorimotor system involves central integration and processing of all the afferent information which includes visual, vestibular, and cervical proprioceptive inputs, and motor program execution through the cervical muscles, resulting in contribution to the maintain head posture and balance. (9) In brachial plexus injury, there is weakness in the muscles surrounding the affected joint; joint capsule and ligaments become abnormally loose which might affect the receptors transmitting proprioceptive information from the affected extremity. (10) As there is anatomical proximity with connection in the afferent - efferent loop between the upper limb and cervical spine, sensorimotor affection to the affected limb might also affect the cervical proprioceptive sensation.

Reaction time can be termed as the time taken between the application of a stimuli and the time taken to conduct an appropriate, timely response to it. [11] Chronicity in the pathology of neck can affect the receptors to get disrupted which can delay reaction time; it includes both sensory and motor alertness. The factors affecting sensory as well as motor system can affect the reaction time as well. In general, the time interval between application of a stimulus and initiation of movement is increased. [11]

Normal cervical proprioception is necessary for BPI patients when they commute in public transport vehicles or visit the crowded places. It is important to assess cervical proprioception as their affected shoulder is kept in shoulder sling for 6months or longer depending on recovery of motor control at shoulder joint. There is a scarcity of literatures on the cervical proprioception as well as Simple Reaction Time in patients with brachial plexopathies. Hence this study was undertaken to compare Cervical Proprioception and Simple Reaction Time in subjects with Brachial Plexopathies and Healthy Adults so that assessment and treatment protocol would have inclusion of these two factors.

2. Materials and Methods

A comparative study was conducted at Hand OPD Department of Physiotherapy, Physiotherapy School and Centre, Seth G. S. Medical College, KEM Hospital, Mumbai and received ethical clearance from the Institute. It was conducted for duration of one year. Total of 60 participants participated in the study and were conveniently divided into one of the two groups namely, Group A consisting the Brachial Plexus patients (30) and Group B consisting age matched Healthy Adults (30).

Subjects were screened according to the inclusion and exclusion criteria and only those eligible were included in the study. The inclusion criteria were as follow: Brachial plexus injury patients and age matched healthy adults willing to participate involving dominant hand. Both genders - males and females with age group of 18 to 25 years. Duration - Cases of BPI from 1 month to 1 year of injury having partial or global brachial plexus injury. Age matched normal healthy adults for group B. Exclusion criteria for group A are as follows: Any complaints of pain in extremity, recent or previous trauma to cervical spine, recent or previous surgery done to cervical spine, psychological conditions, Bilateral BPI and clavicular and upper limb fractures. Exclusion criteria for group B include any neurological conditions or musculoskeletal dysfunctions.

Baseline assessment was done for both the groups. Cervical proprioception (degrees) for right and left side and Simple Reaction Time recorded.

3. Study Procedure

A] Cervico - cephalic Relocation Test [12, 17, 28, 29, 30, 31]

- Subject, wearing a headband with a laser beam device attached, was seated blindfolded on a chair with backrest.
- The target (40cm diameter circle with concentric circles at every 1cm) was placed at 90cm distance.
- The subject was instructed to memorize the neutral head position.
- The subject performed a maximal rotation of the head to left or right for approximately two seconds, then attempt to find the initial reference position with a maximum of precision. The point was recorded.
- A mean of 6 trials were taken for both side rotations.
- If the mean value was higher than a threshold value of 7.1 cm or 4.5 degrees, the subject were considered as inaccurate.
- Target used to determine laser values (in degrees) of JPE based on the formula:

$$\textbf{Angle} = \tan^{-1}\frac{[\text{error distance}]}{[90\text{ cm}]}$$

Fig 1 and 2: Subject wearing headband with a laser beam device attached, seated blindfolded on a chair with backrest and Target with concentric circles at 90cm distance.

B] Simple Reaction Time [11, 18, 32, 33, 34]

- The Deary - Liewald reaction time task software was used to assess the Simple Reaction time.
- It is free to use software available online. Downloaded from: https: //datashare. is. ed. ac. uk/handle/10283/2085
- Subjects were seated comfortably in a room with adequate light and silent atmosphere.
- Headphone was provided to avoid noise and other disturbances.
- For the SRT, one white square was positioned approximately in the center of a computer screen, set against a blue background.
- The stimulus to respond is the appearance of a diagonal cross within the square. Each time a cross appeared, participants had to respond by pressing a key as quickly as possible.
- Each cross remained on the screen until the key was pressed, after which it disappeared and another cross appeared shortly after.
- 8 practice trails are given before the actual time recorded.
- 20 real time trails were performed by the participants.
- The participant has to respond by pressing the space bar as quickly as possible.

Figure 3: Subject performing Simple Reaction Time

Outcome Measures

- Cervical Proprioception measured in degrees (x^0). ICC 0.52 - 0.81 and 0.49 - 0.77 for absolute and variable errors, respectively.
- Simple Reaction Time measured in milliseconds (ms). Version 3.1, reliability 0.94

4. Results

60 patients participated in the study as two groups - Group A: included Brachial Plexus injury patients and Group B: included age matched Healthy Adults.

Group A showed significantly higher values in the mean error angle for right rotation of Cervical Proprioception (Group A - 7.307; Group B - 4.587; p<0.0001).

Group A showed significantly higher values in the mean error angle for left rotation of Cervical Proprioception (Group A - 8.153, Group B - 4.299; p<0.0001).

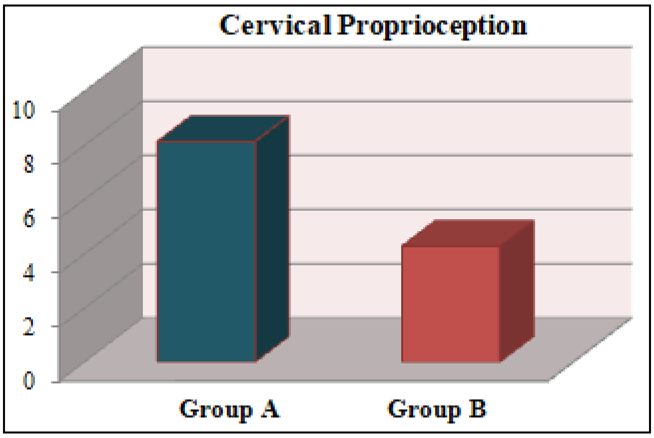
Group A showed significantly delayed Simple Reaction Time (Group A – 386.01, Group B – 288; p<0.0001).

The numbers of Brachial Plexus injury type patients participating in the study were 26 global BPI and 6 partial BPI. Out of 30 patients of Brachial Plexus injury participating in the study, there were 14 pre and 16 post - surgical BPI.

Group A showed significantly higher values in the mean error angle for right rotation of Cervical Proprioception (Group A - 7.307; Group B - 4.587; p<0.0001).

Table 1: Comparison of cervical proprioception for right rotation between group A and group B using unpaired t test

Cervical Proprioception	Group A Right	Group B Right
MEAN	7.307	4.587
SD	1.850	1.993
SEM	0.3378	0.3639
95% CI	6.616 – 7.998	3.842 – 5.331
P VALUE	< 0.0001	

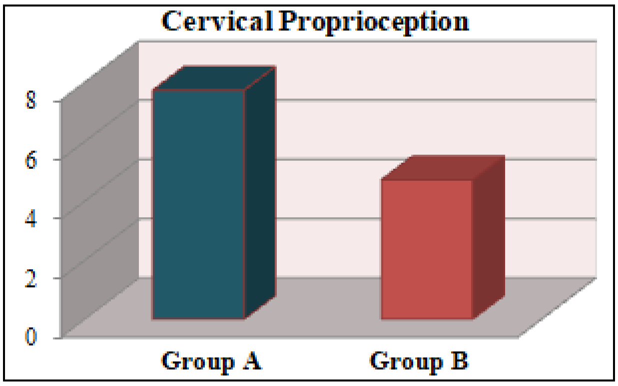


Inference: The Cervical Proprioception mean error angle for right rotation is significantly higher in Brachial Plexus injury patients as compared to age matched Healthy Individuals.

Group A showed significantly higher values in the mean error angle for left rotation of Cervical Proprioception (Group A - 8.153, Group B - 4.299; p<0.0001).

Table 2: Comparison of Cervical Proprioception for left rotation between group A and group B using Mann - Whitney test

Cervical Proprioception	Group A Left	Group B Left
MEAN	8.153	4.299
SD	2.054	3.041
SEM	0.3750	0.5552
95% CI	7.386 – 8.920	3.164 – 5.435
p VALUE	< 0.0001	

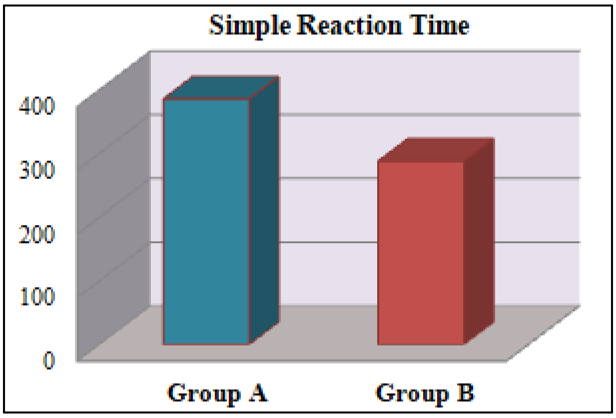


Inference: Mean error angle of Cervical Proprioception for left rotation is significantly higher in Brachial Plexus Injury patients as compared to Healthy Individuals.

Group A showed significantly delayed Simple Reaction Time (Group A – 386.01, Group B – 288; p<0.0001).

Table 3: Comparison of Simple Reaction Time between Group A and Group B using Mann - Whitney test

Simple Reaction Time	Group A	Group B
MEAN	386	288
SD	125.72	28.72
SEM	22.95	5.243
95% CI	339.1 – 433.0	277.3 – 298.7
P VALUE	< 0.0001	



Inference: The Reaction Time is significantly delayed in Brachial Plexus injury patients as compared to Healthy Individuals.

5. Discussion

According to C. Buz Swanik et. al., proprioceptive sensation depends on both the afferent and efferent pathways. The Brachial Plexus transmits this proprioceptive (afferent) information to the central nervous system (CNS). Appropriate response is then transmitted back through the plexus along the efferent (motor) pathway. [6]

Deran et. al. explained that the proprioceptive sensation is perceived by sensory stimuli from mechanoreceptors which are located in the joints, tendons, joint capsules, and skin. In the upper extremity, Brachial Plexus transmit these inputs to the central nervous system through efferent neurons. [19] The data is registered by the CNS and then it converts these inputs to a motor response via the brachial plexus with efferent neurons. Deafferentation of these proprioceptive receptors due to lesion occurring to brachial plexus may affect the motor coordination. [10]

Depending upon the level and severity of lesion to brachial plexus, it can significantly result in loss of muscle power throughout the involved upper limb. They become abnormally weak which might affect the receptors transmitting proprioceptive information from the affected extremity to the cervical spine, in turn affecting the cervical proprioception sensation. [10]

Susan et. al. concluded that following any injury or lesion to peripheral nerves, it can be assumed that proprioception may be also be affected, due to close relationship between motor function and sensory feedback, particularly in conditions where longstanding muscle paresis restricting the normal function. [35]

A study by Elizabeth et. al. explains the connection between Brachial plexus and CNS. It says that the sections of axons that comprise a nerve root are enclosed within a short glial segment which lies close to the surface of the spinal cord or brainstem when it crosses the transitional zone between the central and PNS. The transitional zone is that length of rootlet that contains both central and peripheral nervous tissue. [36] Brachial plexus injury can affect this transional zone.

As there is anatomical proximity present between the PNS of upper extremity and the CNS along with connection in the afferent - efferent loop between the upper limb and cervical spine, sensorimotor affection to the affected limb might also affect the cervical proprioceptive sensation.

It is possible that only the efferent pathway is disrupted, as supported by the strength deficits in muscles of upper limb. However, in postganglionic brachial plexus lesions, conduction velocity throughout the proprioception loop remains sufficient to grossly detect the cervical joint position. Moreover in these patients proprioceptors situated in deep cervical muscles remain intact as the injury is distal to this site. Because of these two reasons brachial plexus injury patients were able to perform the test though they had increased error angle. [12]

Sainburg et. al. in the study on the patients with proprioceptive deafferentation resulting from sensory neuropathies, found a large variability in the timing of agonist/antagonist muscle activation, which resulted in the loss of motor coordination and joint position sense. [14]

According to Hannu et. al, proximal lesions or impairment of muscular and articular receptors or by alteration in afferent integration and tuning can primarily affect proprioceptive sensation. [37]

According to study conducted by Abichandani et. al., proximal injuries or trauma has been hypothesized to cause lesion of receptor - bearing structures or functional impairment of muscular and articular receptors. This would have an impact on proprioception as well as on motor control and thus provide an explanation for the disturbances in sensory - motor control of the neck found in these patients. [38]

Thus, this explains greater error angles when tested for cervical proprioception in brachial plexus injury patients as compared to age matched healthy adults.

The significant affection or delayed simple reaction time in brachial plexus injury patients (group A) can be explained as follows:

According to Ovais et. al., Reaction is a purposeful voluntary response to an external stimulus. Reaction time requires intact sensory system, cognitive processing, and motor performance. It is a good indicator of sensorimotor coordination and performance of an individual. In brachial plexus injury patients, there is affection to the sensorimotor pathway which can be the hypothesized reasoning for delayed reaction time in these individuals. [39]

The sensory impairment in the uninjured/non - affected extremity found in patients with brachial plexus injury suggests that this lesion leads to central modifications in the hemisphere contralateral to the uninjured limb. [42]

According to Iwamura et. al., at some level in the brain for contralateral alterations to be reflected in the ipsilateral hemibody, there must be an inter - hemispheric transfer of information. Sensory input is perceived and processed in the contralateral primary somatosensory cortex but to some extent there is also an ipsilateral cortical response to peripheral stimulation. [43]

Because of the alteration in ascending information coming from the injured limb it could lead to reduced activity in the intralaminar nuclei thus can cause reduced sensations in both injured and the uninjured limb. [44]

Feng et. al. concluded that brachial plexus injuries affecting the dominant right extremity are associated to a large sensory impairment in the uninjured extremity. This is due to the fact that greater cortical functional reorganization is observed in patients with lesions to Brachial Plexus when the dominant extremity is affected as compared to the non - dominant extremity. [45]

This suggests that a relatively more extensive adaptive process may occur in the central nervous system following an injury to the dominant extremity. The long - standing loss and/or disuse of the dominant hand may degrade the sensorimotor efficiency of both the dominant and the non - dominant upper limb.

Brachial plexus injury affecting dominant side has a greater impact over sensorimotor representations along with reduction in the plasticity of hemisphere contralateral to the dominant limb. [46]

Anne et. al. explained presence of underlying central mechanism for the sensory changes occurring in the "uninjured" body side. Changes in somatosensory sensibility after unilateral amputation show reorganization of the contralateral motor and sensory cortex. Changes also occur in the ipsilateral cortex, representing the nonamputated body side where a lateral displacement of the cortical motor map and an enlargement of the sensory maps of the intact limb have been observed. [47]

Werhahn et. al. have reported a decrease in the excitability of the motor cortex ipsilateral to an upper - limb amputation compared with that of control subjects. There is a decrease in the excitability of the ipsilateral motor cortex. [48]

According to Karl - Heinz et. al. found abnormal sensory function at the contralateral side in patients with unilateral neuropathic pain. A significant change in the sensory function of the affected side can produce effects on the contralateral sides as well. Reason behind this phenomenon is the presence of a central component in processing the pain and controlling sensory function bilaterally. The intensity of neuropathic pain plays important role in contralateral sensory changes. ([49] Thus, when the dominant side is affected there is a sensory dysfunction in the non - affected non dominant side. This explains why the reaction time was significantly higher on contra lateral nonaffected side in the study population.

6. Conclusion

The present study concludes that Cervical Proprioception showed a significant affection in Brachial Plexus injury patients along with delayed simple reaction time when compared with age matched Healthy Adults. This means though the recovery of motor function has been the primary focus in Brachial Plexus reconstruction, restoration of basic sensory functions such as perception of joint position and movement, called proprioception, is essential to all physical activities of daily life and is a precondition for optimal muscular control, coordination, and stability. Hence, this study highlights the need for assessing cervical proprioception and simple reaction time in Brachial Plexus evaluation as well as management for the same should be a part of rehabilitation protocol after Brachial Plexus injury.

Conflicts of Interest

None

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