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Analyzing Changes in Nerve Excitability Parameters for Diagnostic Insights in Cervical Radiculopathy

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Abstract

Introduction: Chronaxie and Rheobase are essential measures of nerve excitability and conduction. This study examines the influence of cervical radiculopathy on these parameters and their potential diagnostic value. Thirty patients with cervical radiculopathy and thirty healthy controls were evaluated for Strength-Duration Curve (SDC) parameters. Findings indicated significantly elevated Rheobase (7.0 mA vs. 5.04 mA) and prolonged Chronaxie (0.36 ms vs. 0.25 ms) in the patient group ($p < 0.05$). The study underscores the clinical utility of SDC in refining diagnostic precision and guiding targeted therapeutic interventions. **Methods**:This cross-sectional observational study included 30 patients with cervical radiculopathy and 30 healthy controls (ages 33-47, matched for age and gender). Rheobase and Chronaxie were measured using a microcontroller-based diagnostic muscle stimulator. Independent t-tests were conducted to compare SDC parameters between groups. Ethical approval was obtained from the IAMR Research and Ethics Committee. **Results**: Cervical radiculopathy patients exhibited significantly higher Rheobase (7.0 ± 0.35 mA) compared to controls (5.04 ± 0.24 mA) ($p < 0.001$). Chronaxie values were also prolonged in patients (0.36 ± 0.03 ms) versus controls (0.25 ± 0.02 ms) ($p < 0.001$). These findings suggest impaired nerve excitability and conduction, supporting SDC as a complementary diagnostic tool. **Discussion:** The study confirms that cervical radiculopathy significantly alters SDC parameters, reflecting underlying neurophysiological dysfunction. The prolonged Chronaxie and elevated Rheobase suggest axonal damage and demyelination, reinforcing SDC's potential in differential diagnosis. These findings align with previous research on lumbar radiculopathy and peripheral neuropathy. **Conclusion** : SDC testing provides valuable diagnostic insights into cervical radiculopathy. Elevated Rheobase and prolonged Chronaxie serve as objective markers of nerve dysfunction, enhancing diagnostic accuracy and treatment planning. Future studies should explore longitudinal assessments and therapeutic interventions targeting SDC parameter normalization.

Keywords: Strength-Duration Curve, Rheobase, Chronaxie, Cervical Radiculopathy, Neurophysiology, Diagnostic Precision

Introduction

The strength-duration curve (SDC) is a fundamental tool in neurophysiology, offering invaluable insights into the relationship between the intensity and duration of electrical stimuli required to elicit responses in biological tissues. Introduced in the early 20th century, the SDC has significantly advanced the understanding of nerve excitability and muscle response, becoming a cornerstone of both clinical diagnostics and therapeutic interventions. Over the decades, its application has expanded beyond foundational research to address a wide array of clinical challenges, including the evaluation of nerve injuries, peripheral neuropathies, and muscular disorders. The enduring relevance of the SDC lies in its ability to provide precise, objective data about nerve and muscle function, making it an indispensable tool in both experimental and applied medical science.

Its simplicity and reliability have ensured continued use alongside more advanced diagnostic technologies.[1]

At its core, the SDC is a graphical representation where the x-axis denotes the duration of an electrical stimulus in milliseconds (ms), and the y-axis represents the stimulus intensity, typically measured in milliamperes (mA). Two critical parameters define the curve—rheobase and chronaxie—which serve as key markers of nerve excitability. Rheobase refers to the minimum current intensity required to elicit a response when the stimulus duration is infinitely long, while chronaxie indicates the shortest duration needed for a stimulus at twice the rheobase to evoke a response. Together, these parameters provide a quantitative framework for assessing nerve health, offering clinicians a means to detect subtle changes in nerve function that might escape detection through other diagnostic methods. This versatility makes SDC an invaluable bridge between theoretical neurophysiology and practical clinical application.[2]

The historical significance of SDC is underscored by its role in early efforts to diagnose nerve injuries and monitor recovery. While newer diagnostic tools like medical imaging and electromyography (EMG) have introduced sophisticated capabilities, SDC remains a reliable, cost-effective, and patient-friendly option. Its utility is particularly pronounced in cases where advanced imaging or EMG fails to provide a complete picture, such as instances of mild functional impairments or ambiguous imaging results.[3] The straightforward nature of SDC

testing also allows it to be implemented in a variety of healthcare settings, from specialized neurology clinics to primary care facilities. By analyzing SDC parameters, clinicians can refine electrical stimulation protocols to optimize safety and efficacy, particularly in the context of neurostimulators, pacemakers, and neuroprosthetics. Additionally, its role in rehabilitation settings, where it aids in tracking nerve recovery, highlights its dynamic contributions to patient care.[4]

Beyond diagnostics, the clinical applications of the SDC extend into therapeutic realms. For example, in devices like cochlear implants and neurostimulators, the SDC helps optimize electrical stimulation parameters, ensuring effective therapy while minimizing risks to surrounding tissues. Similarly, in rehabilitation, SDC testing enables personalized intervention strategies for patients recovering from nerve injuries or managing chronic neurological conditions. Its ability to illuminate the intricate dynamics of nerve function at a granular level makes it a critical tool in the development of innovative therapeutic strategies and devices.[5] Moreover, the non-invasive nature of SDC testing offers a patient-friendly alternative to more invasive diagnostic methods, further cementing its importance in modern medical practice.

This study seeks to explore the diagnostic potential of SDC in cervical radiculopathy, with a specific focus on the C6 and C7 spinal segments. These segments are commonly implicated in cervical radiculopathy, making them ideal for examining the utility of SDC as a diagnostic tool. By comparing SDC parameters between patients with cervical radiculopathy and healthy controls, the research aims to bridge critical gaps in understanding nerve excitability changes associated with the condition. Furthermore, the study underscores the clinical relevance of SDC as a complementary diagnostic method, highlighting its advantages in terms of patient comfort, cost-effectiveness, and diagnostic precision. The findings from this research aspire to pave the way for integrating SDC testing into routine diagnostic protocols, enhancing patient outcomes and advancing the broader understanding of cervical radiculopathy's pathophysiology. The aim is to investigate the changes in nerve excitability parameters (Rheobase and Chronaxie) in patients with cervical radiculopathy with spinal segment C6-C7 and to assess their diagnostic potential compared to healthy individuals[6]

Methodology

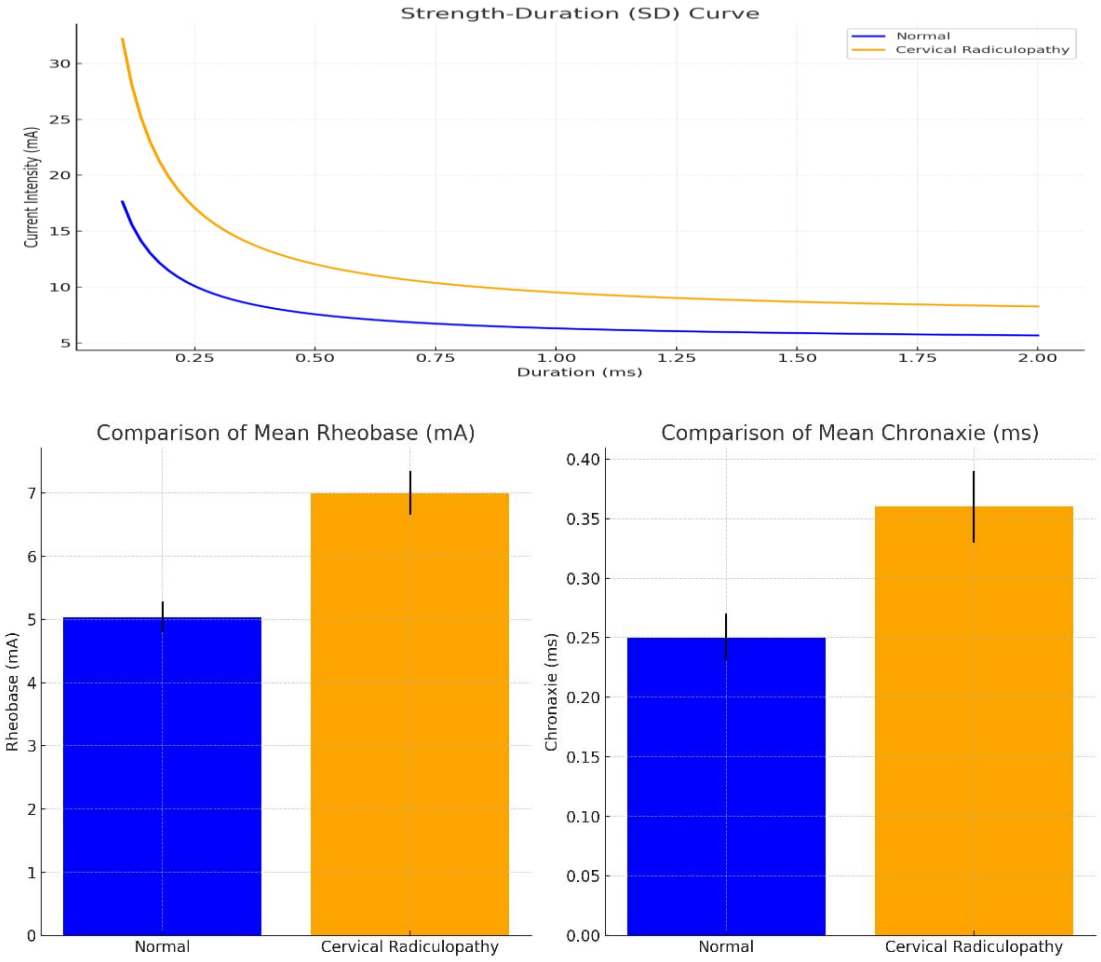
30 patients with cervical radiculopathy and 30 healthy controls (ages 33-47, matched for age and gender). Rheobase and Chronaxie were measured using a microcontroller-based diagnostic muscle stimulator. Independent t-tests were conducted to compare SDC parameters between groups. Ethical approval was obtained from the IAMR Research and Ethics Committee. The SDC testing was conducted using an electrical stimulator with an interrupted direct current feature (W-P Instruments Inc.). The machine's wiring from the mains to the plug box and the device itself was intact and properly insulated. The dispersive electrode, measuring 300 cm^2, and the small active stimulating electrode, measuring 4 cm^2, were both covered with gauze and soaked in a hypertonic sodium chloride solution before each test. The subjects were instructed to rest in a comfortable seated position with the arms supported to relax the muscles. The anode electrode was placed posteriorly just over the bony prominence of c6 spinal segment,to ensure precise stimulation of the targeted nerve root. And secured with a micropore medical tape for stability. For the triceps, the active electrode was placed over the triceps radial head, where the largest contraction was felt when the subject extended the elbow against resistance. For the ECRL, the subject was asked to extend and radially deviate the wrist, and the active electrode was placed on the largest muscle mass about two-thirds down the forearm, where the motor endplates are located. The electrode was adjusted to find the point of strongest contraction with the least stimulation, and then secured to prevent movement during testing.[7] A standard clinical technique was used, where pulse widths were successively decreased (300, 100, 50, 38, 10, 7, 5, 3, 1, 0.8, 0.6, 0.4, 0.3, 0.1, and 0.05 ms) while recording the current (mA) needed to produce a minimal visible muscle contraction. Testing started with the longest pulse duration (300 ms), and the current intensity was gradually increased until a minimal contraction was observed. This process was repeated for each progressively shorter pulse duration. The system is tested by attaching the leads and electrodes to the terminals and placing the electrodes 10 cm apart, initially on the palmer surface of hand. After switching on the machine, the intensity was gradually increased until the current was felt.[8]

Results

The Rheobase and Chronaxie values were summarized for both the Normal and Cervical Radiculopathy groups. Descriptive statistics, including the mean, standard deviation (SD), and range, were calculated for both groups. The following table summarizes these parameters:

Condition	Mean Rheobase (mA)	SD (Rheobase)	Mean Chronaxie (ms)	SD (Chronaxie)
Normal	5.04	0.24	0.25	0.02
Cervical Radiculopathy	7	0.35	0.36	0.03

These values indicate that individuals with cervical radiculopathy have significantly higher Rheobase values, meaning a higher electrical stimulus is required to produce a response. Additionally, their Chronaxie values are prolonged, suggesting impaired nerve conduction.



Cervical radiculopathy patients exhibited significantly higher Rheobase (7.0 ± 0.35 mA) compared to controls (5.04 ± 0.24 mA) ($p < 0.001$). Chronaxie values were also prolonged in patients (0.36 ± 0.03 ms) versus controls (0.25 ± 0.02 ms) ($p < 0.001$). These findings suggest impaired nerve excitability and conduction, supporting SDC as a complementary diagnostic tool. The results from the t-tests revealed that both Rheobase and Chronaxie values were significantly higher in the cervical radiculopathy group compared to the healthy control group. The p-values for both parameters were < 0.001, indicating strong statistical significance.

Discussion

This study sheds light on the significant neurophysiological differences observed in patients with cervical radiculopathy compared to healthy individuals, with particular emphasis on alterations in nerve excitability and conduction properties. These findings provide crucial insights into the pathophysiology of cervical radiculopathy and underscore the impact of the condition on peripheral nerve function. One of the primary findings was the elevated rheobase in patients with cervical radiculopathy.[9] Rheobase refers to the minimum electrical stimulus intensity required to elicit a response from the nerve.Patients demonstrated significantly higher rheobase values compared to controls, as illustrated by the triceps and Extensor Carpi Radialis muscle data (7.0 mA in patients versus 5.1 mA in controls) and (6.0 mA in patients versus 3.5 mA in controls) respectively. This increase in rheobase suggests reduced nerve excitability, potentially due to demyelination, axonal loss, or other structural changes in the affected nerves.[10] Reduced excitability could hinder the transmission of neural signals, contributing to the clinical symptoms of weakness and sensory deficits commonly observed in cervical radiculopathy. Another critical finding was the prolongation of chronaxie in the patient group. Chronaxie represents the time required for a nerve to respond to an electrical stimulus that is twice the rheobase. Patients exhibited delayed response times, with triceps chronaxie values averaging 0.36 ms compared to 0.25 ms in controls. Additionally, Extensor Carpi Radialis (ECR) chronaxie values in patients averaged 0.34 ms compared to 0.22 ms in healthy controls.[11] This prolongation is indicative of impaired nerve conduction, likely stemming from pathological alterations such as conduction block or slowed propagation due to nerve compression.

Prolonged chronaxie reflects the degree of dysfunction in the affected nerve pathways and serves as an objective measure of the severity of neural impairment in cervical radiculopathy.[12]

Conclusion

SDC testing provides valuable diagnostic insights into cervical radiculopathy. Elevated Rheobase and prolonged Chronaxie serve as objective markers of nerve dysfunction, enhancing diagnostic accuracy and treatment planning. Future studies should explore longitudinal assessments and therapeutic interventions targeting SDC parameter normalization.

Clinical Implications

The observed neurophysiological changes have important clinical implications for the diagnosis and management of cervical radiculopathy. Increased rheobase and prolonged chronaxie could serve as valuable electrophysiological markers for assessing nerve function and monitoring disease progression. These parameters could also help differentiate cervical radiculopathy from other conditions with overlapping symptoms, such as peripheral neuropathy or brachial plexopathy. Furthermore, understanding demographic influences on nerve excitability may guide personalized treatment strategies, particularly in tailoring interventions for older patients who may experience more pronounced neural impairments.

Limitations and Future Directions

While this study provides significant insights, it is important to acknowledge certain limitations. The sample size may limit the generalizability of the findings, and additional studies with larger cohorts are warranted. Furthermore, exploring the relationship between neurophysiological changes and clinical outcomes, such as pain severity and functional recovery, could enhance the applicability of these findings. Future research should also investigate the potential reversibility of these neurophysiological alterations with therapeutic interventions, such as physical therapy, pharmacological treatments, or surgical decompression.

Conflict of Interest Statement
The authors declare no conflicts of interest.

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