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Peripheral Motor and Sensory nerve conduction studies in normal infants and children in Eastern India

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I. Introduction

Infancy and childhood are important landmarks in human physiology. This is the time when all the systems (including peripheral nervous system) of our body develops and gradually matures, to attain the normal state of adults.

Peripheral nervous system development, is age dependent and begins in utero, hypo-developed at birth and attains maturity at the age of 5-6 years of age[1]. Electro physiologic values, therefore, change significantly in different age groups in first few years of life and are different from adult values[2]. However there is very little information about the progress of evolution of the peripheral nerves with its correlation with nerve conduction parameters[3] Standard values of nerve conduction parameters are essential in evaluating normal development and infantile neuromuscular disorders[4].

Practical scenario shows that, the infants and children do suffer from a good number of peripheral nerve disorders[5]. Although appropriate history and physical examinations are important in diagnosis, evaluation of progression and prognosis of the disease, these may not be easily available or performed in young children and also findings may be difficult to interpret. Therefore objective measurements of nerve conduction velocity are useful and important[6]. Also, this investigation is important, as it is a relatively painless procedure requiring little co-operation from the patient[7].

Nerve conduction studies, are considered one of the most important and sensitive parameters to determine the nerve maturation and also to exclude any peripheral nerve abnormality. Nerve conduction studies allow noninvasive analysis of nerve physiology and function, and also confirm clinical diagnosis of peripheral neuropathies with a high degree of sensitivity and specificity.

There are very few data on normal electrophysiological parameters of motor and sensory fibers during nerve maturation, and almost no complete study has been reported from India, till date. Therefore, this innovative study will help to explore the evolution and changes in nerve conduction studies during the first few years of life and will also determine the normal values of nerve conduction in pediatric population in eastern India. Thus it will also help in evaluating development in normal children and infants and also in early detection and prognosis of different types of peripheral nerve disorders in this population.

There are a fair number of studies of normal healthy individuals of different countries, race, and environment by Norris et al. 1953, Thomas et al. 1960, Johnson et al. 1961. Moosa et al 1972, Chung et al. 1975, Hyllienmark et al. 1995, K. Ja Cho et al. 1999. In all these studies either the subjects were older than 6 years or the study was selective for specific either motor or sensory nerve fibers.

The relationship between conduction velocity of motor nerve fibers and age has been studied by many authors (Cerra et al.1962, Blom et al. 1968, Chung et al. 1973). Their findings are not valid specifically for children under six.

The purpose of this study is to determine the conduction velocities of motor and sensory nerve fibers in children less than six years of age of eastern India, before these values attain adult values.

`No such detail definite study in eastern India, has been undertaken, for the pediatric population. Hence this study will be very useful to determine the normal motor and sensory conduction studies in both upper and lower extremities, in eastern India children upto 6 years.

II. Review Of Literature

Peripheral nervous system (PNS) maturation in infancy and childhood varies with age[5]. Normal function of the peripheral nerves is based on proper morphological integrity and relationship between axons, Schwann cells and connective sheaths, which depend on the correct development of all these components[8].

It was as early as in 1850, Helmholtz[9], first reported that he had measured the rate at which nerve impulses travel. Later in 1870, Helmholtz and Baxt summarized some of their findings in regard to the human median and ulnar nerves. They noted the conduction velocity in these nerves varied from 30 m/s to 90 m/s.
Subsequently neurophysiologists further showed that conduction velocity bears a linear relationship to the diameter of the nerve fiber in which the impulse travels[10] and in myelinated nerves is particularly dependent on the thickness of myelin sheath.

Peripheral nerve myelination begins as early as 15th week of gestation and continues throughout the first 5 to 6 years of life after birth. The total number of myelinated fibers is smaller than the adults. Axonal diameter and myelin thickness are less than adults. Hence the ratio of the diameter of an axon without myelin to that of a fully myelinated fiber (G-ratio) is above normal, a finding indicating hypomyelination – is seen in first few years of life[11] . During this period there is progressive increase in the thickness of the myelin sheath in relation to the axon diameter. Remodeling of the nodes of Ranvier also occurs in first few years with internodal distances reaching a peak at 5 – 6 years, resulting in an optimal conduction velocity. Thus a gradual increase in nerve conduction velocity seen during infancy and early childhood is likely due to the results of – i) gradual increase in the number of large fibers resulting an increase in the axonal diameter and ii) a gradually completed myelination of nerve fibers.

Peripheral nerve myelination is a highly coordinated process involving Schwann cell proliferation, radial sorting, and myelin assembly overlap (Martin and Webster, 1973; Webster et al., 1973; Stewart et al., 1993)[12]. Myelin increases the speed of neural conduction in axons, and defects in myelination cause a variety of congenital and acquired neurological disorders. A number of studies have demonstrated that myelination requires the interaction of Schwann cells with molecules in the basement membrane (BM), which assembles at the surface of axon–Schwann cell units (Moya et al., 1980; Carey and Todd, 1986; Eldridge et al., 1987)[13].

Normal function of the peripheral nerves is based on proper morphological integrity and relationship between axons, Schwann cells and connective sheaths, which depends on the correct development of all these components[14] .

Most important determinants of nerve conduction velocity (NCV) is the presence of the amount of myelin and diameter of axons[15]. Actually, the conduction velocity more closely correlates with axon diameter than fiber (axon & myelin) diameter[16]. Therefore in assessing the relative contribution of conduction velocity (C.V.) of a nerve, both axon and myelin are important and they are linearly proportional [4]. There is an optimal ratio of axon diameter to total fiber diameter (and therefore to myelin thickness), at which the C.V. is maximized[16]. Hence (as Saunders 1946 stated) the total fiber diameter is equal to the axon diameter plus twice the sheath thickness, is also related to axon diameter.

Another important factor is the internodal distance, which also varies linearly with fiber diameter (as discussed by Boycott, 1904; Kubo and Yuge, 1938; Vizoso and Young, 1946).

Hence any of these variables, axon diameter, total fiber diameter, myelin sheath thickness or internodal distance – controls conduction velocity, is consistent with the available experimental evidence, favoring a relationship between conduction velocity and fiber diameter[17]. The fiber diameter (axon diameter and myelin thickness) increases slowly but continuously between five months of gestation until the fourteen years of age[18]. But the significant increase is seen upto the age of six years; during this period of growth, C.V. increases in direct proportion to the increase in length of the nerve[19].

Therefore the C.V. of peripheral nerves is slower in infants and children in direct proportion to the axon diameter (Thomas et al. 1960, Schulte et al. 1986) and amount of myelination (Moosa et al. 1972, Chung et al. 1973) [20] .

III. Materials & Methods

3.1 Study design –

A prospective and co-relational study was conducted at –
Department of Physiology, I.P.G.M.E. & R., Kolkata, Department of Neurology, Bangur Institute of Neurosciences, Kolkata. with the favour of Department of Pediatrics, I.P.G.M.E & R, Kolkata.

Total 123 healthy, normal infants and children born at term, from a healthy mother, ranging in the age from one month to six years, were taken as "CASES" and were divided into six groups , as follows –

Group	Age of the Case	No. of cases
I	1 month – 6 months	18
II	> 6 months – 12 months	19
III	> 12 months – 24 months	21
IV	> 24 months – 36 months	21
V	> 36 months – 48 months	21
VI	> 48 months – 72 month	23

Total 123

Among them, 61 are male children and 62 are female.

Total 60 healthy normal adult subjects, ranging in the age between 20 – 40 yrs, were taken as "Control group", with 30 males and 30 Females.

3.2 Details of examination

Nerve conduction studies were done using a " RMS Aleron 201 Electromyograph" [21] with a software RMS EMG NCV EP MK II installed.

No sedation was used in any case. Room temperature was maintained in the range of 25 – 28^{o}C using an air conditioner. Skin temperature was maintained in the range of 32 – 34^{o}C [4] . The nerves were stimulated supra-maximally by a surface stimulating bar pad electrode. Pulses of 0.1 msec duration were used throughout the study. For motor conduction studies AND Sural sensory conduction study, surface electrodes were used, with a disc ground electrode. For sensory conduction studies from the fingers, ring electrodes were used. The electrode-skin impedance was reduced to below 5 kΩ, using a mild abrasion with spirit-cotton, and conductive jelly was used on the stimulating and recording electrodes.

Nerve conduction velocity (NCV) , Compound muscle action potentials (CMAPs) determination in motor conduction studies done in Median and Ulnar nerves in upper limbs and in Tibial and Peroneal nerves in lower limbs. In sensory conduction studies, the sensory nerve action potential (SNAP) onset latencies and SNAP amplitudes were measured from Median, Ulnar nerves in upper limbs and from Sural nerve in lower limbs. "F" responses studies were undertaken in Median and Tibial nerves and the mean latencies of the "F" waves were measured (from the average of continuous 15 recorded responses) to have an idea about the proximal conduction pathways also.

As there is no significant right to left asymmetry in the normal nerve conduction parameters, the sides were chosen as right in upper limbs with left in lower limbs or vice versa, in the children and adults.

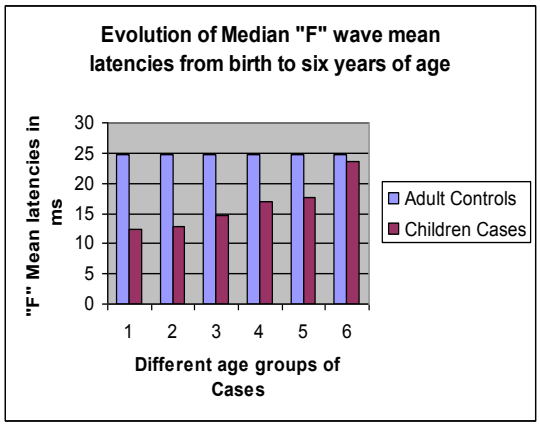
The unilateral examination of a limb was done to simplify the procedure, for easy and quick execution of the test and for better compliance of the subject.

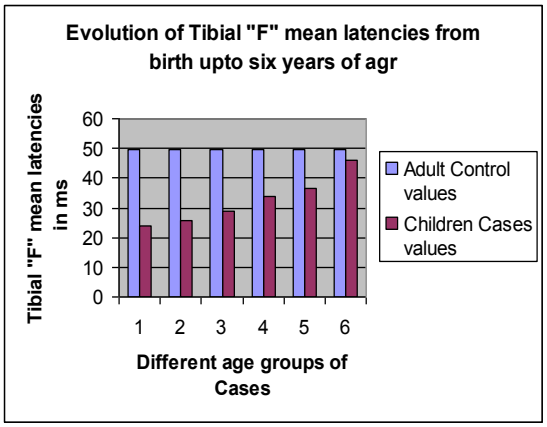
IV. Results & Analysis

Detailed nerve conduction studies were performed and the individual motor NCV and CMAP amplitudes of Median, Ulnar, Tibial and Peroneal nerves were tabulated. "F" wave recordings were also done in Median and Tibial nerves and the mean latencies of each individual were tabulated. In sensory conduction the SNAP onset latencies and SNAP amplitudes of each Case were taken into account. Then the Mean and standard deviation (S.D.) of all the above mentioned parameters, of all these nerves were calculated.

It is seen that the increase in motor NCV values in all the nerves is linear and progressive. The progression pattern in both the upper limb & lower limb nerves are almost same, but there is a distinct difference in normal values all throughout, between upper and lower limbs. Mean MCV of Tibial nerve is the lowest, compared to the other three nerves

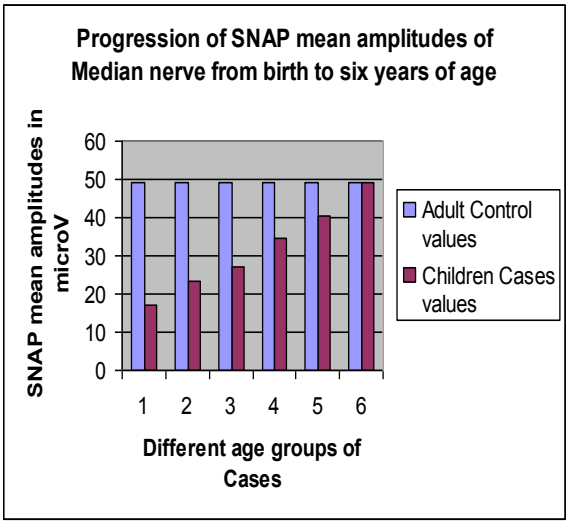
In spite of gradual linear progression in SNAP latencies, there is no significant difference in mean values of SNAP onset latencies , between upper and lower limbs. The same linear gradual progression is seen in both upper and lower limbs in mean "F" latencies of Median and Tibial nerves. Motor NCV values are higher in upper limbs than lower, as seen above, the "F" latency values are more in lower limbs than upper. It is also seen that "F" latency mean values in lower limbs are almost twice that of in the upper limbs, and it persists all throughout. In neonatal group (Group –I) , or just after birth the "F" mean latencies are around one-half of the adult mean values, both in upper and lower limbs. Pattern of progression of mean latencies in both upper and lower limbs are also similar, as shown below.

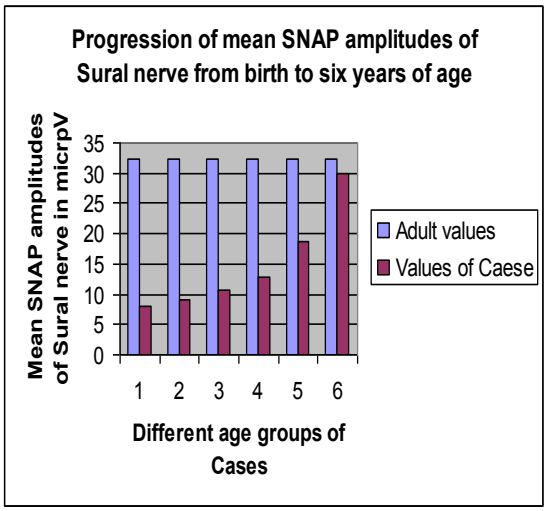




Throughout the study, the CMAP amplitudes of Tibial are greater than the CMAP amplitudes recorded from other remaining studied muscles. Again in the study, CMAP amplitudes of Peroneal are the smallest of all the studied muscles. The CMAP morphology was always biphasic (negative-positive), the greater component being the negative. In more than half of the cases, CMAP (from ADM) of Ulnar nerve showed a double negative peak, in all age groups, including Cases and Controls.

The mean SNAP amplitudes in neonatal group (Gr -1) are almost one-third, in comparison to the normal adult values.





There is progressive increase over the next three to four years. SNAP amplitudes of Median and Ulnar are always greater than Sural, in all ages, throughout the study.

It may also be noted, that like conduction parameters, the pattern of curves in both CMAP and SNAP amplitudes are also almost similar in nature.

In this context, we are going to calculate the multiplication factors of the mean values of all the parameters, to reach the adult values.

The multiplication factors mean a definite number, which when multiplied with the mean values of the corresponding NCS parameters of that age gives the normal adult values. Also, vice versa, the normal NCS values of a certain child may be estimated by dividing the corresponding normal adult NCS values with that multiplication factor, as shown below.

Tibial Nerve

Group	Values in Children		Multiplication Factor	
	NCV (m/s) (Mean ± S.D.)	Fwave latency (ms) (Mean ± S.D.)	NCV	F wave latency
I	28.79 ± 3.73	23.76 ± 3.29	1.64	2.08
ii	32.70 ± 3.72	25.9 ± 2.47	1.45	1.90
III	34.70 ± 2.18	28.95 ± 2.14	1.36	1.70
IV	37.59 ± 2.02	33.82 ± 2.2	1.26	1.46
V	41.53 ± 1.45	36.44 ± 2.23	1.14	1.35
VI	47.72 ± 4.11	45.93 ± 5.31	0.99	1.07

Normal Adult value of NCV of Tibial Nerve (mean ± S.D.) : 47.51 ± 3.79
Normal Adult value of F wave latency (mean ± S.D.) : 49.5 ± 4.1

This above calculation will be of immense help in day to day evaluation of NCS data of pediatric population, before thy attain the adult values, and will greatly help in early diagnosis and management of different types peripheral nerve disorders in these age groups.

V. Discussion and Conclusion

Standard values of nerve conduction parameters are essential in evaluating infantile neuro-muscular diseases. In order to obtain such standard values in our areas of Eastern India, we investigated the progressive evolution of both motor and sensory nerve conduction in infants and children before they attain the normal adult values, by using a noninvasive technique, using surface electrodes.

This study agrees with the contention that in the neonatal group

(Group –I) MNCV mean values are about one-half of those of normal adult values[4] , and that most rapid increase occurs during the first year of life [2,5,8,] and these agree with previous studies (Cai and Zhang 1997; Parano et al, 1993; Vecchierini-Blineau and Guiheneuc 1984; Audry-Chaboud et al.; 1984, Cruz Martinez et al., 1977; Wagner and Buchthal 1972; Gamstorp and Shelburne, 1965; Baer and Johnson, 1965; Thomas and Lambert,1960;). There was a gradual linear increase in mean MNCV values in both upper and lower limbs[24], and this feature also corroborates with the previous studies (Miller and Kuntz,1986; Kwast et al. 1995).

These features also agree with histological changes determinant of conduction velocity in myelinated fibers (Waxman 1980)[22]. This study also concurs that adult values of both MNCV of upper and lower limbs are reached during the first four to six years.

It may also be noted that, at birth the diameter of motor nerves is one half that of the adult.

Garcia and Calleja et al., 2000, found a differential evolution of "F" wave latency, according to age; a very slow increase, stabilization and sharp increase afterwards. Here in this study also, it was found that, there was a slow but steady linear increase in "F" latency upto the age of three years, then almost static in 4th year and again there was a significant increase in "F" latencies from 4 – 6 years of age, which also agrees with the previous study. Such evolutions are explained taking into account two infantile physiological features influencing the determination of "F"-wave latency, namely, growth of the extremity and the curve of MNCV[4].

Baer and Johnson(1965)[23] found that, the MNCV of Tibial nerve was slightly lower than of the Peroneal nerve. In other studies a similar finding was observed either between Tibial and Median nerves (Cruz Martinez et al, 1978) or between Tibial and Ulnar nerves (Vecchierini-Blineau and Guiheneuc, 1984), and all these suggested that among all Tibial MCV is the lowest. Therefore, this study results further expand these observations which have a pathophysiological basis that remain unresolved.

Cai and Zhang, 1997 described that the CMAP amplitude of Tibial (from Abductor Hallucis) is the first to reach the adult values around 2 years of age. Here also we found the same pattern, with Tibial CMAP reaching the lower normal limit of adult values by the age of 2 years. In contrast, all other CMAP amplitudes of median, ulnar and Peroneal nerves show that the CMAP gets doubled around 4 years of age and reaches the normal adult values between 4-6 years, as suggested in the previous investigations (Miller and Kuntz,1986; Cruz Martinez et al, 1978a)[24].

All the CMAP morphologies was similar and always biphasic with initial negativity, except for ulnar (from ADM) where we frequently got a double negative peak, as also found by Thomas and Lambert, 1960 [8] ; this should be taken into account to avoid misinterpretation.

Although SNAP peak latencies has been discussed in different studies, onset latencies have been studied in only a few (Garcia and Calleja et al., 2000). Here we found all the neonatal SNAP onset latencies are almost one-half of the normal adult values , which is in accordance with the previous report. The onset latencies are always lower in Sural nerve, compared to Median and Ulnar nerves, in all ages throughout the study.

Regarding SNAP amplitudes, here we found some statistical differences, as compared to the other previous reports. As observed earlier, SNAP amplitudes reached adult values by the age of 2 years (Gamstorp and Shelburne, 1965; Cruz Martinez et al, 1978) [25]. But in contrast, we found the SNAP amplitudes reached the adult values by 3 – 4 years of age, i.e. almost similar to most CMAP amplitudes. Nevertheless, after 4 years, similar to other studies, there is a lesser increase or static in SNAP amplitudes, which can be accounted for by the increase in temporal dispersion of potentials as a result of longer distances involved in relation to extremity growth (Cruz Martinez et al, 1978b); confirmation of this hypothesis demands for future studies determining the SNAP areas. Differences in the distance from the skin to the nerve is another influencing factor in the amplitudes of SNAPs (Buchthal and Rosenfalck, 1966; Wilbourn,1994). Though most of the studies opted for orthodromic stimulation of sensory nerves, here we did antidromic stimulations and in both the types SNAP amplitudes are all the same, as suggested by Meythaler JM et al, 1994 that, SNAP amplitude of a single fascicle was paradoxically equivalent to the SNAP amplitude of the entire nerve[26].

As SNAPs were studied in all the children studied here, we prefer and suggest to investigate the SCV together with MCV; absence of SNAP from birth or within 6 months of age , should be considered not as a technical pitfall but an indication of abnormality.

To summarize, this procedure provides detailed data on the gradual evolution of peripheral motor and sensory nerve conduction in infants and children up to 6 years of age, and also the relationship between the normal infants and adult values, with also the relationship between electrophysiological parameters and extremity growth.

References

[1]. Shin J Oh, Clinical electromyography and nerve conduction studies Baltimore : University Park Press, 1984, P 107 – 139.

[2]. Parano Enrico , Uncini Antonio, De Vivo DC,. Lovelace Robert E ,: Electrophysiologic correlates of peripheral nervous system maturation in infancy and childhood, J. Child Neurol, 1993; 8 : 336-338.

[3]. Sertel H., Sosa M. De , Moosa A. : Peripheral nerve maturation in English, West Indian and Turkish newborn infants, Developmental Medicine and Child Neurology, 1976; 18 (4) : 493 - 497.

[4]. Berciano J, Garica A, Calleja J, Antolin FM, : Peripheral motor and sensory conduction studies in normal infants and children, Clin Neurophysiol., 2000 ; III : 513 – 520.

[5]. Vecchierini-Blineau MF, Guiheneuc P. , : Motor nerve conduction velocity in children : normal values and application to a few pathologic cases, Rev. Electroencephalogr Neurophysiol Clin. 1984 Apr ; 13 (4) : 340 - 348.

[6]. Kyoung Ja. Cho : Motor nerve conduction velocity in newborn infants and Children , Yansei Medical Journal, 1987; 28 (3) : 172-175.

[7]. Dunn HG, Buckler W.St .J, .Morrison G.C.E : Conduction velocity of motor nerves in infants and children, PEDIATRICS , Nov.1964 ; 34 (5) : 708-727.

[8]. Lambert E.H., : Neurophysiological techniques useful in the study of neuromuscular disorders, Res. Publ. Ass. Res.Nerv Ment. Dis., 1960.; 38 : 247 – 250.

[9]. Helmholtz H.L.F. von : Vorlanfiger Bericht fiber die Fortpflanzungsgeschwindigkeit der Nervenreizung, Arch. Anat. Physiol. Wiss. Med., 1850 ; p.71

[10]. Gasser H.S. and Grundfest H. : Axon diameter in relation to the spike dimensions and the conduction velocity in mammalian A fibres, Amer. J. Physiol. , 1939 ; 127 : 393.

[11]. David C, Preston, and Barbara E. Shapiro : Electromyography and Neuromuscular disorders , Clinical – Electrophysiologic Correlations; 2nd edition, 2005; Chapter 8 : 89 – 90.

[12]. Stewart HJ, Morgan L, Jessen KR, Mirsky R : Changes in DNA synthesis rate in the Schwann cell lineage in vivo are correlated with the precursor–Schwann cell transition and myelination. Eur J Neurosci , 1993 ; 5:1136 –1144.

[13]. Eldridge CF, Bunge MB, Bunge RP, Wood PM : Differentiation of axon-related Schwann cells in vitro. I. ascorbic acid regulates basal lamina assembly and myelin formation. J Cell Biol, 1987 ; 105:1023–1034.

[14]. S. Kaplan, E. Odaci, B. Unal, B. Sahin, M. Fomaro : Development of the peripheral nerve, International Review of Neurobiology, 2009; 87 : 9 – 26.

[15]. Gillespie M.J., Stein R.B., : The relationship between axon diameter, myelin thickness and conduction velocity during atrophy of mammalian peripheral nerves, Brain Res. , Jan 1983 ; 259(1) : 41 – 56 .

[16]. Stephen G., Waxman M D, : Determinants of conduction velocity in myelinated nerve fibres, Muscle & Nerve, Apr. 1980 ; 3 (2) : 141 – 150.

[17]. Sanders F.K., Whitteridge D. : Conduction velocity and myelin thickness in regenerating nerve fibers , J. Physiol. 1946 ; 105 : 152 – 174 .

[18]. Schroder J.M., Bohl J., Brodda K. : Changes in the ratio between myelin thickness and aon diameter in the human developing Sural nerve , ActaNeuropathologica, Nov. 1978 ; 43 : 169 – 178.

[19]. Hopkins A.P., Lambert E.H. : Age changes in conduction velocity of unmyelinated fibers , Journal of Comparative Neurology, Feb. 1973 ; 147 (4) : 547 – 552 .

[20]. Allie Moosa, Victor Dubowitz : Postnatal maturation of peripheral nerves in preterm and full term infants, The Journal of Pediatrics, Dec. 1971 ; 79(6) : 915 – 922.

[21]. Aleron 201 Electromiograph , Recorders Medicare Systems (R.M.S.) RMS EMG NCV EP MK II.
[22]. Waxman SG: Determinants of conduction velocity in myelinated nerve fibers, Muscle Nerve 1980 ; 3: 141 – 150.
[23]. Baer RD, Johnson EW : Motor nerve conduction velocities in normal children, Arch Phys Med Rehab 1965; 46 : 698-704.
[24]. Miller RG, Kuntz NL : Nerve conduction studies in infants and children, J Child Neurol, 1986 ; 1 : 19 – 26.
[25]. Gamstorp I, Shelburne SA : Peripheral sensory conduction in ulnar and median nerves of normal infants, children and adolescents, Acta Pediat Scand 1965; 54 : 309 – 313.
[26]. Meythaler JM, Tuel SM, Cross LL, Reichart RT, Wertsch JJ : Electrophysiologic analysis of SNAP amplitude in orthodromic and antidromic studies, Electromyogr Clin Electrophysiol, Sep 1994; 34(6) : 323-329.