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Short Latency Mechanically Evoked Peripheral Nerve and Somatosensory Potentials in Newborn Infants

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Summary

Mechanically evoked short-latency potentials were recorded from ten newborn infants ranging in gestational age from 36 to 42 wk and from a 3-month-old infant during natural sleep. Potentials were recorded from four electrode configurations: (1) over the peripheral nerve at the wrist: distal-proximal; (2) over the peripheral nerve at the axilla-deltoid insertion; (3) over the cervical spinal cord and cerebrum: C_{II}-F_{pz}; and (4) over the cerebrum: C_4-F_{pz}. All subjects produced clear potentials from configurations 1, 2 and 3. Configuration 4 produced reliable potentials only in one newborn who was large for gestational age (42 wk) and the 3-month-old infant. Average peripheral nerve conduction velocities were 26 m/sec from wrist to axilla and 29 m/sec from axilla to neck. No significant correlation was found between conceptional age and nerve conduction velocity. The application of this technique could allow lesion localization in peripheral as well as central portions of the somatosensory pathway of newborns.

Sensory evoked potentials recorded by surface electrodes using computer averaging have been utilized in the newborn nurseries. Auditory (1, 2, 18, 23, 25, 26, 28, 31) and visual evoked potentials (14, 15, 30) have been well described and found to reflect peripheral (auditory) and central (auditory and visual) maturation in addition to indicating pathologic changes. Somatosensory evoked potentials in newborn infants have so far only been obtained by electrical stimulation of peripheral nerves (5, 6, 9, 10, 12). Electrical stimulation ensures a synchronous activation of peripheral nerves, but lacks specificity with regard to the type of fibers activated and their dermatomal origin. In addition, electrical stimulation fails to activate nerve endings and to detect changes of their function. Further, electrical stimulation may be experienced as uncomfortable.

Recently, we have described a method for recording potentials along the somatosensory pathway, from peripheral nerve to cerebral cortex, evoked by mechanical cutaneous stimuli (tapping on fingernails) in adults (21).

The purpose of this study was to examine the mechanically evoked potentials in newborns as means for the evaluation of maturation of the somatosensory pathway.

MATERIALS AND METHODS

Ten newborn infants ranging in conceptional age from 36 to 42 wk, as well as a 3-month-old infant, were studied in the newborn nurseries at the medical center and at the neurophysiology laboratory in the department of Neurology at the University of California, Irvine. All were examined and found to be normal with no neurologic impairments. Gestational age was estimated; weight, length, and head circumference were measured, and appropriateness of weight for gestational age was evaluated. All subjects were tested within 36 hr of birth, except for the 3-month-old infant and a 36-wk gestational age infant who was studied 4 days after birth.

The method for mechanical stimulation and recordings has been described previously (21), and a number of modifications were made to accommodate the newborn population tested. In brief, subjects were tested immediately after feeding during spontaneous sleep. No monitoring of sleep stage was attempted because short latency components are independent of sleep stage (9). They were lying on a flat, padded surface, and the hand stimulated was supported by one examiner with the fingers taped to a flat board. Because of the subjects' small size, precautions against stimulus-generated electrode movement artifacts were taken. Thus, care was taken that no other part of the hand was in touch with the supporting board. The surface on which subjects lay, the finger-supporting board, and the mechanical stimulator were placed on three separate stands. The stimulus was a 50-msec duration square electric pulse transduced by a moving coil vibrator. The vibrating tip had a 2 mm diameter hemispheric surface which, in the resting state, was perpendicular to and just in contact with the nail of the middle finger. Stimuli were delivered at a rate of 4/sec. The skin temperature of the proximal part of the fingers was measured and maintained at approximately 35°C throughout the recording session, which lasted approximately 20 min.

Tin disc electrodes, 6 mm in diameter, were placed over the median nerve at the wrist and near the axilla, over the insertion of the deltoid muscle, over the second cervical vertebra (C_{II}), over the contralateral hand area of the cortex (C_4), and over the middle of the forehead (F_{pz}). The electrodes were filled with conducting jelly, attached to the skin by collodion glue, and secured with tape. Electrode resistance was kept below 5 kOhms. Four electrode configurations were used simultaneously: (1) wrist distal-wrist proximal; (2) axilla-deltoid insertion; (3) C_{II}-F_{pz}; and (4) C_4-F_{pz}. The potentials were amplified (× 200,000) and filtered using a band-pass of 30 to 3,000 c/sec (3 dB down point; 6 dB/octave slopes) and averaged over 50 msec after the onset of the electric pulse delivered to the vibrator. One thousand repetitions were included in each average, and at least two repetitions of each average were performed to assess reproducibility. The amplifiers and averaging computers used at the medical center and at the neurophysiology laboratory were of different manufacturers, whereas the stimulating module was the same. White noise was used to mask the sound produced by the vibrator.

Distances between the fingernail and the distal wrist electrode, between the distal wrist electrode and the axilla, and from the axillary electrode to the electrode at C_{II} were measured. Nerve conduction velocities were then calculated for each segment by dividing the respective distance by the latency difference between the potentials recorded at each end of a segment. The latency of the potentials recorded at the wrist was normalized to a 7.5 cm distance for all subjects. The latency of the wrist potentials includes both the coupling time of the mechanical stimulus to the fingernail and the neural conduction time. The normalized latency of the wrist potentials is a size-normalized value termed normalized distal latency.

RESULTS

Figures 1 to 3 include the potentials recorded from newborns at different gestational ages.

The potentials recorded by the two electrodes over the median nerve at the wrist had a biphasic waveform with an initial negative peak at an average latency of 6.6 msec followed by a positive peak. This compound action potential was occasionally followed by a large biphasic potential at 25 to 50 msec (*e.g.*, Fig. 3) which was always associated with a measurable mechanical movement

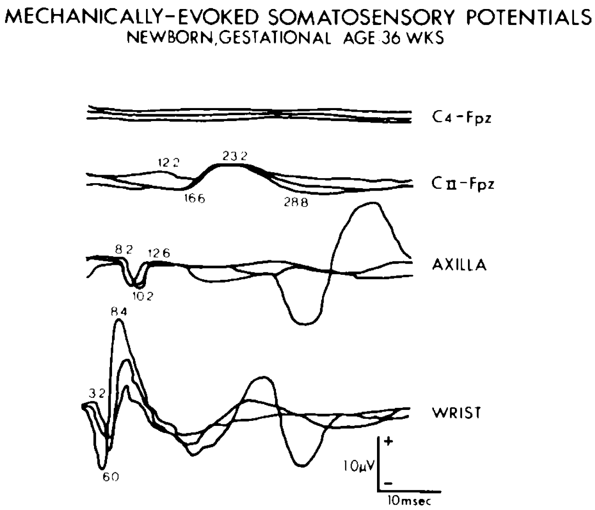

Fig. 1. Mechanically evoked somatosensory potentials from a 36 wk gestational age newborn infant. Components were marked by their latency in msec. The four channels were recorded simultaneously, and three repetitions of the recordings were superimposed to assess reproducibility. Movement artefact at the wrist and axilla recordings in one of the repetitions. Absence of components in the C_4-F_{pz} recording.

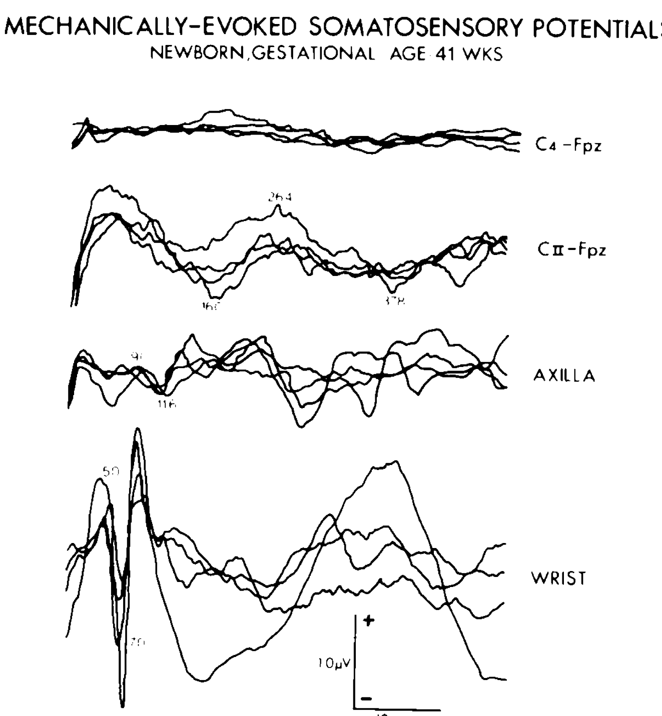

Fig. 2. Mechanically evoked somatosensory potentials from a 41 wk gestational age newborn infant. Components were marked by their latency in msec. Four channels were recorded simultaneously, and four repetitions were superimposed to assess reproducibility. Absence of clear components in the C_4-F_{pz} recording.

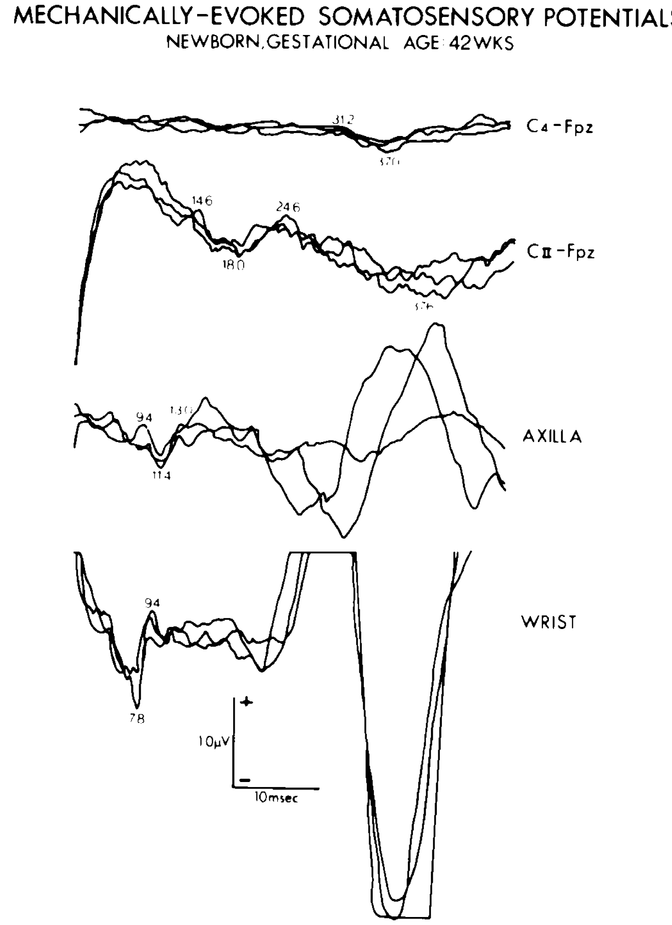

Fig. 3. Mechanically evoked somatosensory potentials from a 42 wk gestational age newborn infant. Components were marked by their latency in msec. The four channels were recorded simultaneously, and three repetitions were superimposed to assess reproducibility. Reproducible potentials in the C_4-F_{pz} recording. Movement artefact at the wrist and axilla recordings.

in the forearm resulting from the tapping. This latter potential was thus assumed to be an electrode movement artefact and was not analyzed further.

The electrode over the median nerve near the axilla, referenced to the electrode over the deltoid insertion, recorded a monophasic negative potential at an average latency of 11.0 msec. This potential was occassionally followed by an additional potential, concurrent with the wrist recorded movement artefact (*e.g.*, Figs. 1 and 3), which was thus also assumed to be a mechanically induced artefact.

The electrode over the upper neck, referenced to the middle of the forehead (C_{II}-F_{pz}) recorded an initially negative peak (average latency, 16.4 msec), followed by a positive peak. These potentials were free of movement artefacts.

The C_4-F_{pz} electrode configuration failed to record any components in the majority of the infants studied. The only two subjects that revealed potentials recorded with this configuration were a large-for-gestational-age (42 wk) newborn (Fig. 3) and the 3-month-old infant. In these two subjects, the potentials consisted of a positive-negative complex around 30 msec. The absence of potentials recorded by C_4-F_{pz} in the majority of the infants was not due to technical reasons. This was indicated by: (1) the simultaneously obtained potentials from the other recording configurations; (2) the identical results obtained when the recording and averaging channels were interchanged; (3) the identical results obtained on different recording systems at two different locations (the newborn nurseries and the neurophysiology laboratory); and (4) the detection of these components in a 3-month-old infant.

Table 1. *Gestational age, sex, maturity rating, and measures of peripheral nerve function in the 10 newborns studied*

Newborn	Gestational age (wk)	Sex	Maturity rating	Conduction (wrist/axilla)	Velocity (m/sec) (axilla/neck)	Normalized distal latency (msec)
1	40	F	AGA[1]	25.3	29.8	6.5
2	38	M	LGA	16.4	18.8	5.3
3	40	M	AGA	27.3	32.7	7.5
4	41	F	LGA	23.9	46.7	7.5
5	40	F	LGA	47.6	25.0	7.5
6	42	F	LGA	33.3	24.2	7.3
7	40	F	AGA	21.4	41.2	6.5
8	41	M	AGA	21.7	31.8	7.5
9	37	F	AGA	21.0	22.7	6.4
10	36	F	AGA	25.0	19.5	7.5

[1] AGA, average for gestational age; LGA, large for gestational age.

Table 1 shows the raw neurophysiologic data, in addition to gestational age, sex and maturity rating, for each of the newborns studied.

Average conduction velocities along the median nerve were found to be 26.3 m/sec (S.D. = 9.9) for the wrist to axilla portion and 29.2 (S.D. = 9.2) for the axilla to neck portion. Normalized distal latency was on the average 6.9 msec (S.D. = 0.8). No significant correlation was found between conceptional age and either nerve conduction velocity or normalized distal latency within the age group studied.

DISCUSSION

The result of this study show that with proper modifications the technique for recording mechanically evoked potentials from adults can produce reliable potentials from newborns. The benign nature of the stimulus enables recording during spontaneous sleep with parental consent.

Nerve conduction velocities in the neonatal population studied were about one-half those of the adults. Similar values have been reported by others using electrical stimulation of sensory (12) as well as motor nerves (3, 27, 29). The slowed neonatal conduction velocity (compared to adult values) can be attributed to the smaller diameter of sensory axons in the newborn (13, 20, 24).

Evaluation of nerve endings is difficult using only mechanical stimulation. In adults, a combination of electrical and mechanical stimulation can be used (22), but in this study, we used only mechanical stimulation. Because the exact time of nerve ending activation is unknown, only an underestimation of conduction velocity in the distal portion from fingernail to wrist could be obtained. Improved methods of mechanical stimulation and stimulus monitoring may increase the accuracy in determining conduction velocity of the very distal peripheral nerve by providing more accurate information on nerve ending activation. Digital nerve potentials have been shown to be overwhelmed by movement artefacts in our recording methods (21) and, therefore, cannot be used for this determination.

The potentials recorded between the second cervical vertebra and the forehead were most probably generated at the upper spinal cord and lower medulla (17, 21). The negative-positive constituents of neonatal C_{II}-F_{pz} recordings are similar to the analogous adult components but lack the later negative-positive components recorded from adults using this configuration. In the more mature subjects in this study (41 and 42 wk and 3 months) the initial negative-positive components were followed by a negative component at about 38 msec. In the most mature of these three subjects, a predominantly negative component (37 msec), preceded by a positive peak, was recorded by the C_4-F_{pz} configuration, suggesting the presence of a cortical generator whose function is sensitive to maturation. The absence of recordable cortical potentials in the majority of the infants tested was not due to technical reasons, as explained in "Results," nor most likely to trauma because one of the 36-wk gestational age infants was tested 4 days after a quiet birth. A predominantly surface-negative, premature, cortically generated potential evoked by electrical stimulation has been described for animals (7, 19) and human infants (9). The low-amplitude cortical positivity succeeding this negativity and the gradual increase in amplitude of the positive component with maturation have been explained by rate of development of the superficial cortical synapses (8). The lack of recordable cortical potentials in the less mature infants, although peripheral and nuchal potentials were recorded, indicates slower maturation of the central cerebral pathway as compared with spinal cord and peripheral nerve. A similar conclusion based on inferred central conduction velocities of electrically evoked somatosensory potentials has been previously suggested (10). Beside slowed conduction, temporal dispersion of central neuronal events may give rise to desynchronized central activity resulting in the failure to detect cortical potentials over the scalp. Evidence for such desynchronization in the developmental stages of the brainstem auditory system of cats has been reported (16), and a comparable process may contribute to our findings at the cortex.

Nerve conduction velocities and conceptional age did not show significant correlation. Previous studies, however, have reported significant correlation between conceptional age and motor nerve conduction velocity (3, 4, 11, 27). This discrepancy may be related to a difference between motor and sensory nerves or to the small range of gestational ages included in the present study. The latter explanation is most probable because the maturation of peripheral nerve conduction velocity in infants extends over a period of months and even years (10, 12, 29), and our newborn population has only a 6-week age range. Further investigations should extend the range of conceptional ages studied to elucidate the relations of conduction velocity and of the C_4-F_{pz} potentials to maturation.

Mechanically evoked somatosensory potentials might prove useful in the newborn nursery for the localization of peripheral nerve lesions (*e.g.*, brachial palsy) as well as for following the maturation of the central portions of the pathway after birth, especially in high-risk infants.

The most important advantages of mechanically as compared with electrically evoked potentials are the benign nature of the stimulus, which allows recording during natural sleep, and the ability to avaluate the function of receptors and the very distal nerve endings. With further developments in monitoring the mechanical stimulus and triggering the averager, it may be possible to calculate the actual conduction velocity from the receptors to the wrist, as opposed to the normalized distal latency used in this study. Some disadvantages of mechanical stimulation are that the amplitudes of the evoked potentials are significantly reduced compared to electrically evoked potentials, and mechanical stimulation requires some apparatus not presently standard in electrodiagnostic laboratories.

In conclusion, mechanically evoked potentials can be recorded from newborns. These potentials may be helpful in evaluating the maturation and localization of lesions in peripheral as well as central portions of the somatosensory pathway.

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