# NEURAL CONDUCTION OF THE MYO-MONITOR STIMULUS: A QUANTITATIVE ANALYSIS

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# Neural conduction of the Myo-Monitor stimulus: A quantitative analysis

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The long and expanding history of electrical stimulation in medicine has made it a familiar modality in the everyday practice of neurology, cardiology, and physical medicine. However, in dentistry, it has been used, until recently, only as a test for pulp vitality. Broader use of transcutaneous stimulation for diagnosis of muscle problems and to initiate and control muscle contractions during clinical procedures was introduced to dentistry with the advent of the Myo-Monitor* in 1969. Dentists have since been advantageously utilizing the instrument in a broad spectrum of clinical procedures.[1-8]

Since the long-term success of dental procedures requires an initially relaxed and balanced muscular complex, the first step in the use of the Myo-Monitor is repetitive stimulation to relax the musculature.[9] The instrument is then used for a variety of clinical procedures: production of a muscularly oriented maxillomandibular registration; diagnosis; occlusal adjustment; construction of complete dentures and fixed or removable partial dentures; impressions, including border molding for complete and removable partial dentures; treatment of temporomandibular joint syndromes; reduction of postoperative swelling; and possible transcutaneous neural stimulation for relief of pain.[1, 9, 10]

Because a multiplicity of muscles are involved in executing these clinical procedures, the rationale of transcutaneous stimulation with the Myo-Monitor hinges on the question of whether the stimulus is neurally mediated. The answer to this question has been clouded, because different dental research teams have come to divergent conclusions.[2, 3, 11-13]

## PURPOSE AND SCOPE OF THE INVESTIGATION

The purpose of this investigation was to examine the response of muscles to external stimulation in order to determine whether the resulting contraction was mediated by direct depolarization of the muscle membrane or whether it resulted from

*Myo-tronics Research, Inc., Seattle, Wash.

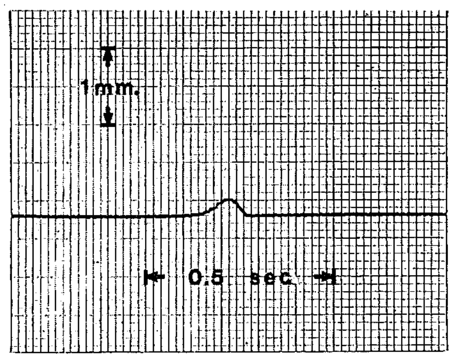


**Fig. 1.** Vertical channel recording from a mandibular kinesiograph shows the 0.2 mm. rise (closure) of the mandible.

an induced neural action potential which stimulated the muscle via the neuromuscular junction. The scope of this investigation was limited to the specific question of whether contractions that follow transcutaneous stimulation with the Myo-Monitor result from direct muscle fiber stimulation[11, 12] or whether the contractions are a response to stimuli transmitted through the motor nerves.[13]

## METHOD OF INTENSITY-DURATION CURVES

A number of methods may be used to give an indication of whether a stimulus is neurally mediated. These include: (1) inspection and palpation,[3, 14-16] (2) electromyographic recording,[15, 17, 18-22] (3) analysis of latency,[15, 17, 19, 23, 24] (4) conduction-velocity measurement,[15, 17, 22] and (5) intensity-duration curves.

Intensity-duration testing was selected as the core method for the experiments, because it is well established and reliable: ". . . the technique that has proved most satisfactory and is in widest use is the recording of the intensity-duration relationship of applied electrical stimuli. It is a straightforward and reliable investigation. The relationship between the strength of the stimulus and its duration in time for a constant response of an excitable tissue gives an accurate measure of the excitability of that tissue."[15]

This method is based on the observation made in 1883 by Erb[25] that has since been firmly established. That is, a long-lasting stimulus will excite both nerve and muscle, whereas a short stimulus will excite only the nerve. Hence, if a stimulus, known to be too short in duration to directly cause muscle depolarization, is applied and muscle contraction results, it can be confidently concluded that the stimulus responsible for the contraction arrived via the motor nerve.

## DESCRIPTION OF THE EXPERIMENT

*Subjects.* The subject sample consisted of six women and four men, ranging from 20 to 60 years of age. One of the subjects was completely edentulous, and none reported clinical symptoms of T.M.J. disorders, occlusal problems, or serious muscle spasm.

*Recording curves.* The technique of intensity-duration recording requires that one detect the occurrence of a consistent minimal response. While detection of threshold

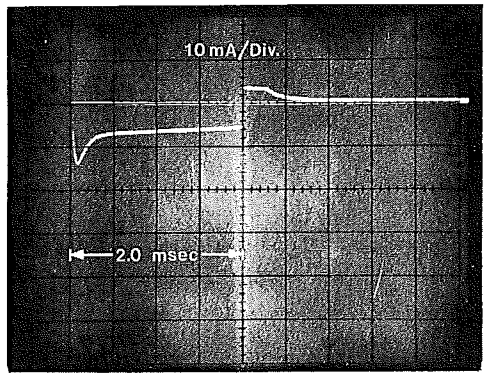


**Fig. 2.** Current wave form of the Myo-Monitor stimulus.

contraction by careful palpation and inspection has been considered adequate and is the means most commonly used in intensity-duration testing, a graphic form of recording has long been sought to lend further objectivity and accuracy to the method.[15] In these experiments, the mandibular kinesiograph,*[26] an instrument which electronically senses and records mandibular movement, was used to precisely measure and record a consistent amount of mandibular rise (closure). Since the amount of mandibular closure is directly correlated to the degree of muscle contraction, precise graphic recording of the amount of closure assured that a consistent contraction was elicited for each of the various stimulus durations. Throughout the investigation, for each subject and at each stimulus duration being used, the intensity of the stimulus was monitored and adjusted to produce the uniform 0.2 mm. mandibular closure (Fig. 1). Kinesiometric recording of consistent contraction proved to be a useful refinement in intensity-duration testing.

*Use of modified Myo-Monitor.* For the purpose of this investigation, a standard Myo-Monitor was specifically modified to permit adjustment of the pulse duration from 0.17 to 3.0 msec. The pulse interval was kept constant at 1.5 seconds, and the output impedance of the unit remained constant at 2,860 ohms. From an oscilloscope display, on-line measurements were made to detect the peak current required for a threshold stimulation at each given pulse duration. The peak currents were recorded at each of six different pulse durations on each of the 10 subjects.

The Myo-Monitor electrodes were applied in strict adherence with the techniques detailed in the *Myo-Monitor Instruction Manual.*[9] Subjects were given a minimum of 10 minutes of threshold stimulation at a pulse duration of 2.0 msec. to eliminate minor muscle spasm and relieve initial anxiety that might occur upon introduction to the research and instrumentation environment.

In each instance, data were first recorded at 0.17 msec. and then recorded sequentially through to 3.0 msec. A period of 2 minutes of stimulation at each pulse duration was given before recording the data. Stimulation current was monitored as the peak value obtained on the current wave form (Fig. 2). After the preparatory stimulations, the peak currents were stable and repeatable in any given subject.

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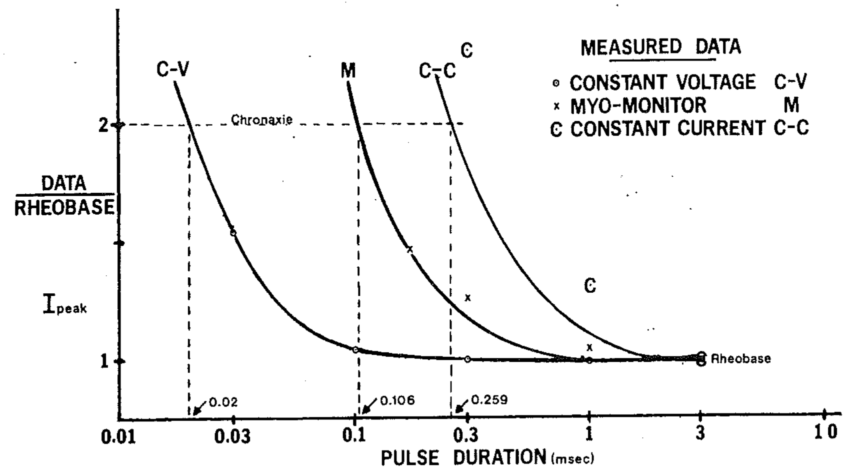


Fig. 3. Comparison of intensity-duration curves as derived with a constant-voltage source, a Myo-Monitor, and a constant-current source. The vertical axis is the relative ratio of peak current to that at 3 msec. The computed curves, shown as solid lines, are plotted relative to the computed peak current at 3 msec. The horizontal axis is the duration of the pulses used for stimulation expressed in milliseconds.

**Table I.** Peak current stimulus as a function of pulse duration

| | *Pulse duration (msec.)* | | | | | |
|---|---|---|---|---|---|---|
| *Patient* | *0.17* | *0.3* | *0.5* | *1.0* | *2.0* | *3.0* |
| CWS | 18.9* | 14.8 | 13.0 | 11.8 | 11.3 | 11.3 |
| PAG | 19.8 | 15.3 | 12.3 | 10.2 | 10.0 | 10.0 |
| PMP | 16.8 | 12.0 | 10.6 | 9.5 | 8.8 | 8.8 |
| MJM | 18.2 | 13.0 | 11.0 | 9.2 | 9.2 | 9.0 |
| AMA | 12.8 | 10.4 | 8.8 | 8.0 | 7.4 | 7.4 |
| KCQ | 18.0 | 12.0 | 10.0 | 8.5 | 8.2 | 8.2 |
| JLP | 12.6 | 8.6 | 7.6 | 6.7 | 6.5 | 6.4 |
| PAS | 20.0 | 14.8 | 13.8 | 12.4 | 12.4 | 11.9 |
| JLD | 18.5 | 13.5 | 11.2 | 10.5 | 10.0 | 9.8 |
| PFC | 13.6 | 11.8 | 8.8 | 8.0 | 7.6 | 7.6 |

*All readings in milliamperes.

## INVESTIGATION TO PROVE APPLICABILITY OF MYO-MONITOR

Because the Myo-Monitor's current wave form is not a familiar rectangular pulse usually found in studies utilizing the intensity-duration method, a separate investigation was conducted to verify that the instrument could be used to study the question at hand. Following the same protocol as outlined earlier, a subject was sequentially stimulated through the same electrodes with a constant-voltage source, the Myo-Monitor, and a constant-current source. In this manner, comparative peak currents could be measured without disturbing the electrode positions, thereby making it possible to assess the relative effect of the Myo-Monitor pulse. The peak current was adjusted for each subject to produce a consistent 0.2 mm. mandibular closure.

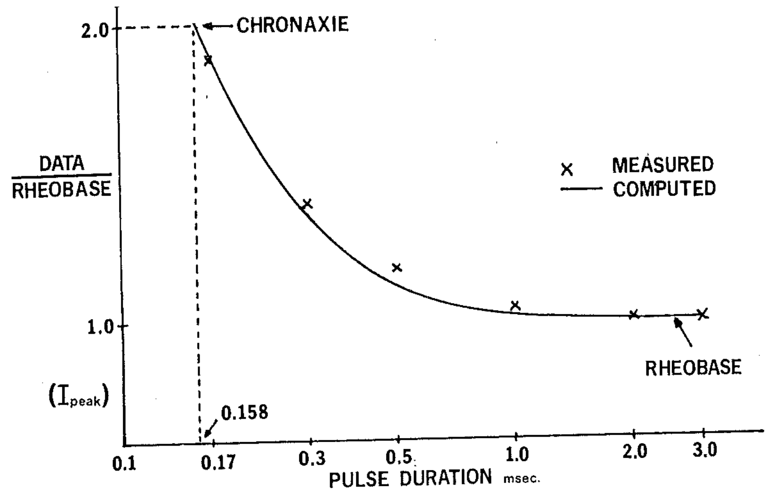


**Fig. 4.** Normalized intensity-duration curve for 10 subjects using the Myo-Monitor. The vertical axis is the mean ratio of peak current to that at 3 msec. The solid line is the computed curve; the *X's* represent the measured data. The horizontal axis is the duration of the pulses used for stimulation expressed in milliseconds.

A mathematical routine employing a least-squares curve-fitting program was used to match the standard intensity-duration curve to the data. As was done earlier, the data were expressed as a ratio relative to the peak current at 3 msec. Fig. 3 shows these ratios along with the computed curves. In the case of the constant-current curve, the poor fit is more apparent than real since there was about a 10 per cent difference between the computed rheobase and the measured peak current at 3 msec. Expressing each as a ratio relative to its own "rheobase" magnifies the errors in curve fitting. Nevertheless, it is readily seen that the constant-voltage source produced the smallest chronaxy (0.02 msec.), while the longest chronaxy was obtained with the constant-current source (0.26 msec.). The Myo-Monitor curve shows an intermediate chronaxy (0.11 msec.) which is to be expected since its output impedance is intermediate between a constant-voltage and constant-current source. The above data support the conclusion that, in strength-duration testing, the difference in results obtained with different types of stimulators is not significant.[27]

Further examination of the data leads to the conclusion that the Myo-Monitor is indeed adequate for use in our investigation. Also, because even the constant-current stimulator did not result in a chronaxy of greater than 0.26 msec., these data alone are strong evidence for neural mediation of the current stimulus.

Contraction of muscles remote from the site of stimulation, for example, the suprahyoid group, was evident by inspection and palpation when the amplitude control was advanced one setting.[3, 9]

## RESULTS

*Data on current recordings.* Peak current records from the 10 subjects are presented in Table I. The spread in peak current values for any given pulse duration re-

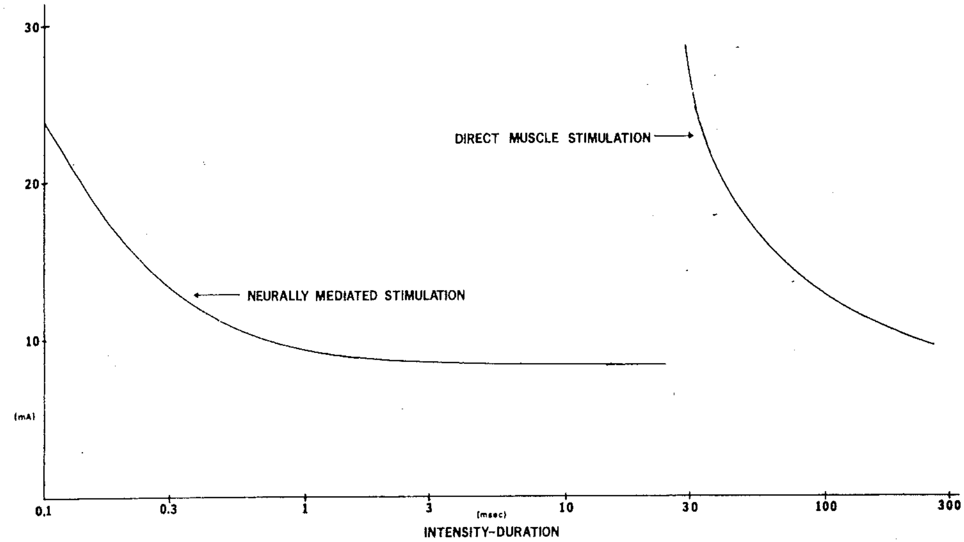


Fig. 5. A comparison of neural stimulation as contrasted with direct depolarization of a denervated muscle (direct muscle stimulation). (Redrawn courtesy of Lenman, J., and Ritchie, A. E.: Clinical Electromyography, Philadelphia, 1973, J. B. Lippincott Company.)

flects the variability in anatomic configuration that is to be expected in a population. Fig. 4 expresses these data in terms of the relative stimulus intensity, which is defined as the ratio of the peak current required for a threshold stimulation at a given pulse duration to that required at a duration of 3.0 msec. (rheobase). Data displayed in this manner tend to normalize the anatomic variability without distorting the critical parameters of the experiment. The mean ratio of the population is plotted in Fig. 4.

*Chronaxy.* The use of transcutaneous stimulation as a diagnostic aid in the determination of muscular innervation hinges on the clear-cut distinction between the excitability curves for nerve and muscle. Among the indices used to quantify intensity-duration curves is the chronaxy, which is defined as the time required for a stimulus of twice the threshold intensity (rheobase) to elicit a consistent response. A mathematical analysis (formula follows) of the data shown in Fig. 4 yields a chronaxy of approximately 0.158 msec. at a relative stimulus intensity of 2.0. Individual chronaxies for the 10 subjects ranged from 0.125 to 0.180 msec.

In all 10 subjects, individual curves followed the same general hyperbolic shape with no significant discontinuities. The data were fitted with a curve of the form:

$$I = I_o \frac{1}{1-e^{-t/k}}$$

where: I = stimulation current (Ma.); $I_o$ = rheobase current (Ma.); t = duration of current pulse (msec.); and k = characteristic of data (time constant, msec.).

Chronaxy values for normal muscles of the face being stimulated through their motor nerve range from 0.02 to 0.3 msec., depending primarily on the stimulator impedance. *If the muscle fibers were being stimulated directly, without the transmission of the signal across the neuromuscular junction, the chronaxy value would be from 50 to 100 times greater* (Fig. 5).[14, 24]

## DISCUSSION

The intensity-duration curves reported for this study support the findings of a previous electromyographic study[13]; that is, the muscle contraction resulting from Myo-Monitor stimulation is generated through a neurally mediated sequence. In that investigation of 15 subjects in which tiny wire electrodes were used, it was reported that, "The evoked E.M.G. was recorded from anterior portion of the temporal, the masseter, anterior ventral of the digastric, the obicularis oris and the buccinator muscles. . . . The Myo-monitor pulse stimulates the nerve trunks of the fifth and seventh cranial nerves at the superior mandibular notch percutaneously and it appeared to have afferent and efferent effects."[13]

However, Bessette and Quinlivan,[12] in another electromyographic study using surface electrodes, reported that they were unable to record a consistent response from the anterior temporal muscle in five subjects, and in one of the five subjects, a wire electrode inserted into the medial pterygoid muscle failed to detect myographic evidence of contraction. These investigators also measured a single latency and used that measurement to calculate what they incorrectly defined as "conduction velocity." From that calculation and their inability to record electromyographic signals from the temporal or the medial pterygoid muscles, they concluded that neural conduction was not involved and the contraction was the result of direct stimulation of only the masseter muscle fibers.

When confronted with differing conclusions, one must look to the conditions of the experiment and the analysis of the data.

In the study by Bessette and Quinlivan[12] which concluded that neural conduction was not involved, in all five subjects, the single latency was measured as the time from start of the stimulus to *peak* of the response. This departure from the conventional definition of latency (the time from start of the stimulus to the *onset* of response) produced a measurement of 3 msec., which then became the basis for their "conduction-velocity" calculations.

To obtain accurate conduction-velocity measurements, stimulation must be done at two points along the nerve and the latency measured for each response. The distance between the two points of stimulation must then be divided by the *difference* between the two measurements of latency so that, in calculating the velocity, an allowance is made for the time it takes the impulse to cross the neuromuscular junction[14, 15, 17, 22]:

$$\text{Conduction velocity} = \frac{\text{Distance}}{(\text{Latency } 2 - \text{Latency } 1)}.$$

*A single latency, as used by Bessette and Quinlivan,[12] does not give a true indication of conduction velocity along the nerve.*

In contrast with peak measurement, the conventional measurement to onset of response would yield a latency of 2 msec. or less (see Bessette and Quinlivan,[12] Fig. 2). The neurally mediated pathway would incur (1) a finite delay in charging dermal capacity of about 0.5 msec., (2) neural conduction time (assuming a conduction velocity of 69 M. per second over a distance of 3 cm.) of 0.46 msec., (3) a delay of 0.3 to 1 msec. at the neuromuscular junction, and (4) an intermuscular delay dependent on electrode placement. A latency of 2 msec.[16] is well within the expected range of a neurally mediated response.

Neither the methodology nor the analysis of the data of the investigation under discussion[12] provided for recognition of neural stimulation that might have occurred. The conclusions that the nerve trunk is anatomically inaccessible to a stimulus and that only muscle fiber stimulation was involved are not warranted either by the method or the data analysis of the experiment.

## SUMMARY

With the introduction of the Myo-Monitor to dentistry, the question has arisen whether the stimulus is neurally mediated[13] or results from direct depolarization of only the fibers of the masseter muscle.[12]

Intensity-duration curves recorded for 10 subjects quantified the relationship between stimulus intensity and the duration of the stimulus required to elicit a consistent contraction response to transcutaneous stimulation via the Myo-Monitor. Individual chronaxies ranged from 0.125 to 0.180 msec., with a mean calculated at 0.158 msec. Stimulating the muscle fibers directly, without transmission of the signal across the neuromuscular junction, would have produced chronaxy values at least 50 to 100 times greater. The distinction is clear-cut. The chronaxy values unequivocally establish transmission of the stimulus across the neuromuscular junction.

In all 10 subjects, contraction of muscles remote from the site of stimulation was evident by inspection and palpation. These data lend support to the conclusion of Choi and Mitani[18] that the Myo-Monitor stimulates the fifth and seventh cranial nerves.

The data derived here correlate with those of other investigations and clearly establish that the transmission of the Myo-Monitor stimulus is accomplished by transcutaneous neural stimulation.

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