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Sympathetic Skin Response Recorded by 4 Channel Recording System

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The main purpose of this article is to determine a method of supporting the sympathetic skin response (SSR) as a sensitive clinical test. Using a non-invasive technique the SSRs are simultaneoulsy recorded by 4 channel EMG machine. Thirty adults (10 women and 20 men, aged 19 to 46 years), normal and healthy, participated in this experiment. Not only did the latencies recorded on both palms respond faster than those on both soles, but the amplitudes measured on the palms were also higher. From these observations, one is bound to conclude that the SSR is not a segmental response but a long systemic response. More than two channel EMG recordings are desirable to see whether or not there is a lesion in any part of the SSR's pathway . Comparing the SSRs made both on the palms and soles simultaneously is recommendable in order to increase the its sensitivity.

Key Words: Sympathetic skin response; sensitivity: non-invasive; 4 channel recording; systemic response

Shahani *et al.* (1984) and Knezevic and Bajada (1985) first recorded the sympathetic skin response (SSR) by using an EMG machine with a non-invasive technique. Opinions still vary widely among researchers on the SSR's clinical significance; some even have questioned whether the SSR is a proper method of evaluating the sympathetic function (Fagius and Wallin, 1980; Montagna *et al.* 1985; Uncini *et al.* 1988; Yokoda *et al.* 1991). However, despite the controversies that surround the method, the SSR, particularly the ease with which it allows the researchers to work, has attracted much serious attention. Indeed, recent studies show that there has been remarkable progress in utilizing the method, and researchers have found the SSR to be effective in such diverse applications as the study of autonomic neuropathy (Knezevic and Bajada, 1985; Martin and Reid, 1985; Montagna *et al.* 1985), the psychophysiology testing, pains and anesthesia measurement (Venables and Christie,1973; Bengtsson *et al.* 1985; Perry *et al.* 1989; Kirno *et al.* 1991), and assessment of autonomic neuropathy in diabetes (Goadby and Downman, 1973; Knezevic and Bajada, 1985; Martin and Reid, 1985; Soliven *et al.* 1987; Niakan and Harati, 1988), and multiple sclerosis (Bengtsson *et al.* 1985; Karazewski *et al.* 1990; Yokoda *et al.* 1991).

But perhaps the SSR's most notable contribution is in both measuring and determining quantitatively the activity of the sympathetic nervous system (Bengtsson *et al.* 1985; Carmichael *et al.* 1941; Goadby and Downman, 1973; Knezevic and Bajada, 1985; Niakan and Harati, 1988; Perry *et al.* 1989). Not only is the SSR influenced by many factors,but is not always reproducible (Day *et al.* 1986; Elie and Guiheneuc, 1990). In addition, SSR was sometimes absent in one site while recorded con-

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stantly in the other sites (Yokoda *et al.* 1991). These shortcomings decrease the sensitivity of the SSR limit its clinical use (Martin and Reid, 1985; Soliven *et al.* 1987), and do not offer reliable indexes of abnormality because of the different technical environment (Martin and Reid, 1985; Albers, 1986; Baba *et al.* 1988). In cases the SSRs are not present, there could be two possibilities to be interpreted as one is real lesion in anywhere in SSR's pathway and /or the other is technical error.

In order to support and to increase the utility of the SSR, we attempted to establish the proper procedure and compare the SSRs, evoked by single electrical stimulation on both palms and soles through the 4 channel recording system.

MATERIALS AND METHODS

Thirty healthy persons who have satisfied the following prerequisites, i.e., those who have not been taking any form of drug that might affect the autonomic nervous system and those who were free from a history of any neuropathic disease, have participated in this experiment. Twenty were male and the other examinees were female. The male participants' mean ages were 29.7 years old (from 15 to 46), the females' were 23.7 years old (from 19 to 38) respectively. Their average height measured 170.4 cm (from 158 to 178.5 cm).

Since this is the first time that all the participants were ever revealed to this kind of experiment, particular cares have been taken. In order not to disturb the examinees' normal emotional stability,we asked them to lie down while we briefed them about the nature,method, and aim of the experiment. Moreover, in order to lessen the examinees' anxiety and to release them from further tension we gave them the same stimulation prior to recording. Throughout the recording, we also kept their palm and sole temperature under strict control, between 33~36℃, by using the YSI telethermometer (Yellowsprings Instrumental Comp., Yellowsprings, OH).

We used the Medelec MS-60 EMG machine for recording setting the frequency filter (band pass) between 1 Hz to 1 KHz: selected an amplification sensitivity ranging between 250 and 1000 μV/div, and the sweep speed showed 500 msec/div (Table 1).

Table 1. Setting for procedure

EMG machine: Medelec MS60
Stimulation: intensity-----100~150V
duration-----0.05 sec
Frequency filter: 1~1,000 Hz
Sweep speed: 500 msec/div.
Amplification: 200~1,000 μV
Recording electrode: surface electrode

For the process, active recording electrodes were placed on the center of the examinees' palms and soles, with the reference electrodes on the back of hands and feet (Shahani *et al.* 1984; Knezevic and Bajada, 1985). The ground electrodes were attached to the abdomen. We used the standard disc electrodes manufactured by Medelec Ltd., for recording the response. An electrical shock with 150 volt intensity of 0.2 msec width was applied to the median nerve at the right wrist and to the tibial nerve at the left ankle. Intervals between shocks were carefully watched not to last more than one minute for each turn. Five shocks were delivered to each nerve (Baba *et al.* 1988), and the results of the stimulation both at the wrist and ankle was recorded simultaneously by EMG which uses a 4 channel recording system.

We defined and timed the latency as one stimulus artifact which lasts to an onset of the response. Pick-to-pick amplitude of each response was also measured and recorded. Mean latency and amplitude for each subject were calculated.

Results are expressed as mean±standard deviation. Student t-test was employed for statistical assessment. A p value of 0.05 was considered statistically significant.

RESULTS

SSRs were not obtainable in 3 subjects on

both sole, regardless of the stimulation sites and intensities at the first trial. But finally we attained SSRs on all the recording sites during the next trials.

As Fig. 1 illustrates, we observed that the SSR, when testing the identical parts of the body, direction (left or right) matters little; but the results show that there was a significant difference in the latencies when we compared different parts of the body that were subjected to the same stimulation. The mean latencies of the SSR in the Rt. median nerve were 1.35±0.03 sec in the Rt. side and 1.35±0.04 sec in the Lt. side, while the mean value of both soles were 1.94±0.13 sec in the Rt. side and 1.95±0.15 sec in the Lt. side. The difference between right and left in the palms and soles appeared small enough to ignore ($p > 0.1$). Nevertheless it turns out that the latencies measured at the palms are considerably faster than that measured at the soles ($p < 0.001$).

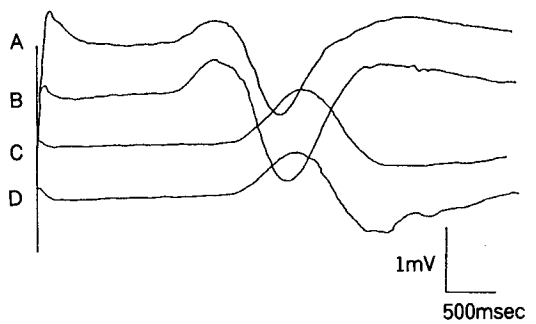

Fig. 1. *Sympathetic skin responses simultaneously recorded on Rt. palm(A), Lt. palm(B), Rt. sole(C), and Lt. sole(D), following an electrical stimulation at the Rt. wrist.*

We almost had an identical result when we stimulated the Lt. tibial nerves in both the palms and soles. The mean latencies of the SSR in the palm were 1.35±0.07 sec in the Rt. side and 1.36±0.08 sec in the Lt. side, 1.92±0.21 sec in the Rt. sole and 1.94±0.27 sec in the Lt. sole. From these results, it is quite clear that the latencies of the SSR shows remarkable uniformity, regardless of the locations of the stimulations (Table 2). The latency might be affected by the influence of height. These results are faster than those of Caucasian (Martin and Reid, 1985; Knezevic and Bajada, 1985), but are same as those of the Japanes (Baba *et al.* 1988).

When we tested the right median nerve, the mean amplitude of the SSR recorded both

Table 2. Latencies of sympathetic skin response (sec)

Stim.	Recording site			
	Rt. Palm	Lt. Palm	Rt. Sole	Lt. Sole
Rt. Median	1.35±0.03	1.35±0.04	1.94±0.13	1.95±0.15
Lt. Tibial	1.35±0.07	1.36±0.08	1.92±0.21	1.94±0.27

(Mean±S.D.)

Table 3. Amplitudes of sympathetic skin response(μV)

Stim.	Recording site			
	Rt. Palm	Lt. Palm	Rt. Sole	Lt. Sole
Rt. Median	3886±876	3556±956	1056±587	1035±560
Lt. Tibial	2542±548	2389±532	1238±441	1223±736

(Mean±S.D)

from the right and left palms were 3886±876 μV and 3556±956 μV. The right and left sole were 1056±587 μV and 1035±560 μV. As we have already observed in the case of the latency, the difference in the stimulation side (right and left) appeared of little worth, whereas the difference in the recording location (palms and soles) was significant enough to notice.

We received almost identical results when we tested the left tibial nerve: their values are, in respect, 2542±548 μV and 2389±532 μV for the right and left palms, 1238±441 μV and 1223±736 μV for the right and left soles (Table 3).

DISCUSSION

Recent studies of the SSR have further developed the methods to observe and evaluate the pathology of the sympathetic nervous system (Shahani *et al.* 1984; Knezevic and Bajada, 1985; Martin and Reid, 1985; Montagna *et al.* 1985; Niakan and Harati, 1988; Perry *et al.* 1989). There are some that still claim that the epidermal layer and the vessels in skin are the verifiable source of the SSR, but it is now largely accepted among researchers that the SSR is the result of the sudomotor's activity (Carmichael *et al.* 1941; Wang, 1958; Geddes and Baker, 1975; Shaver *et al.* 1962; Uncini *et al.* 1988). It would be saying too much if one suggested that the SSR covers all the functions proper to the sympathetic nervous system. Nevertheless, it can hardly be denied that it is an effective and objective tool in measuring the sudomotor's activity which guides and controls the function of the sweat gland (Venables and Christie, 1973; Yokoda *et al.* 1991).

Shaver (1962), in his earlier study, argued the difference between Galvanic skin response and Galvanic skin reflex on the ground that Galvanic skin response can be obtained only when a direct stimulation is given to the peripheral sympathetic trunk or sudomotor. Convincing though it appears, Shaver's distinction fell far short to settle the quarrel; he did not clarify how to can differentiate the Galvanic skin response from the SSR. According to Shaver (1962), the latency of the right palm should always be faster than that recorded from the left palm when the right median nerve at the wrist is stimulated. This may be true for the Galvanic skin response, but as our experiment clearly illustrates there is no such difference in latencies in the SSR. Not that Shaver's accounts for the Galvanic skin response is incorrect, but simply that there is other elements than latency to consider when one sets out to compare the Galvanic skin response with the SSR.

It is then logical to turn to the nerve's structure in order to realize the characteristics of the SSR. The differences in latencies of the SSR must be attributed to its components—afferent pathway, central control, efferent pathway (Wang, 1958; Uncini *et al.* 1988; Elie and Guiheneuc, 1990). And once we shift our focus from the operation of the nervous system—locations and latencies, for instance, to its structure, we begin to understand that all those quarrels that have surrounded the labeling (Galvanic skin response, SSR). Latency amounts to the total sum of the time regardless of the passage of the stimulated site (Wang, 1958; Elie and Guiheneuc, 1990; Yokoda *et al.* 1991).

As we have clearly shown in table II and III, the latencies of the SSR indicates a surprising uniformity no matter what sort of nerves (median or tibial) were tested. The only difference we can observe in this experiment, in the latency as well as in the amplitude, persists whenever we compared the locations of the recorded parts (palm and soles).

However, the difference only serve to reaffirm what we have long supposed to be true; that the reason the latency measured at palms are noticeably faster than that measured at the soles may well be contributed to the various factors,not only an anatomical fact,i.e.,the nerve structure in the upper body part are composed of a larger myelinated fiber (Carmichael *et al.* 1941; Geddes and Baker, 1975), but also somatic sensory conduction, central reticular processing,conduction along preganglionic and postganglionic fibers of cholinergic; and neuroglandular junction (Wang, 1958; Shaver *et al.* 1962).

The same can be true in accounting for the difference of amplitude measured at the palms and soles. Though a few researchers still doubt the clinical value of the SSR (Shahani *et al.* 1984; Knezevic and Bajada, 1985; Martin and Reid, 1985; Montagna, 1985; Niakan and Harati, 1988; Perry *et al.* 1989), this controversy might be due in much occasions to a lack in understanding of the fact that the SSR is composed of three components: afferent pathway, central control,and efferent pathway. Furthermore there is little evidence to show that they have given serious attention to the highly sensitive nature of the test, which is a prerequisite to conduct this kind of experiment successfully. For instance, while the previous researchers almost uniformly report the difference of the latency (Knezevic and Bajada, 1985; Martin and Reid, 1985; Montagna *et al.* 1985; Soliven *et al.* 1987; Baba *et al.* 1988; Elie and Guiheneuc, 1990), few have given thought to the obvious fact that there are a number of variables that could cause the numerical difference: examinee's height and skin temperature, skillfulness of the examiner, types and capacity of the mechanical device used in the experiment, and the emotional status of the examinee (Baba *et al*, 1988; Kim *et al.* 1989; Elie and Guiheneuc, 1990).

More serious reason that turns their experiments into a disputable one can be ascribed to the fact that they used only a single channel machine in recording both the latency and amplitude. In this study the recordings of the SSRs were unsuccessful in 3 healthy subjects on both soles, but successful on both palms. From the next trial we could get all SSRs in these subjects with the same method. Is it possible to conclude that they have any lesion in the pathway of the SSR ? If we use an EMG with single channel recording system, this might be a question. When the SSR was not evoked by five or ten successive stimulation many researchers considered it as absent or as an abnormal response (Niakan and Harati, 1988; Yokoda *et al.* 1991). Because the habituation is a major source of the absent response, successive stimulation should be avoided (Kim *et al.* 1989; Elie and Guiheneuc, 1990). The advantage of the EMG with 4 channel recording system in SSR test is the capability of comparing the SSRs with other recording sites simultaneously. Because they showed definite SSRs on both palms, we could not consider that these subject had a lesion in SSRs pathway in these cases. Many researchers made no mentions of these cases except Yokoda *et al.* (1991) who considered them to be an abnormally unstable response without reasonable proposition. It is uncertain why the SSRs were not obtainable only on soles,but we could avoid the misinterpretation that it is because of a lesion.

To be sure, we too have observed that the amplitude, for instance, varies between and within a single examinee from test to test, showing notable tendency that it diminishes with repeated stimulation.

To sum up: we have learned from this experiment that it is recommended to use four channel recording system and to try again after a period of time in the cases of absent SSR in order to improve and heighten the SSR's sensitivity for clinical value.

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