Clinical Autonomic Research (2019) 29:127–128
https://doi.org/10.1007/s10286-018-0582-3

LETTER TO THE EDITOR

Effects of elastomer roller stimulation of facial skin on autonomic nervous activity

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Received: 20 October 2018 / Accepted: 20 November 2018 / Published online: 23 November 2018

Dear Editors,

Suppressed vagal activity is known to be associated with various diseases, e.g., heart diseases [1] or major depressive disorder [2]. Direct electrical vagus nerve stimulation improves the manifestations of these diseases [1]. In a simpler way, breathing slowly can decrease blood pressure in hypertensive patients by enhancing vagus nerve activity [3]. Therefore, a simple technique for enhancing vagal activity would be useful.

A cooling stimulus on facial skin or a mechanical stimulus that exerts light pressure on the eyeballs lead to a decrease in heart rate via stimulation of the trigeminal nerves. Although these are simple methods that accelerate vagus nerve activity, they can be accompanied by discomfort or pain due to cooling or pressure [4, 5].

Hotta et al. [6] showed that noninvasive mechanical stimulation with a roller-type tool coated with elastomer resin activates low-threshold mechanoreceptive C fibers and induces autonomic nerve reactions in rats. Meanwhile, Nordin et al. [7] reported that the low-threshold mechanoreceptive C fibers of the trigeminal nerves are active when human facial skin is stroked gently. These results raise the possibility that mechanical stimulation of human facial skin with a roller-type tool may trigger the trigeminal nerve and induce autonomic nerve responses. If a decrease in heart rate was caused by this tool, it would constitute a simple and safer means of increasing cardiac vagus nerve activity that is not accompanied by discomfort or pain.

Subsequently, we examined the effects of noninvasive mechanical skin stimulation on autonomic nervous activity in humans and compared them with effects observed with facial cooling stimulation.

Seven healthy college students were asked to rest in a seated position for 7 min three times at 10-min intervals. Mechanical stimulus (a roller-typed stimulation tool, SOMAPLANE, Toyoresin Co., Shizuoka, Japan), ice-cold stimulus (ice and water slurry at approximately 3 °C), and non-stimulus were applied to the left facial skin of the subjects between the cheek and the lower jaw from 5 min to 7 min from the start of the 7-min trial in a randomized order. At each trial, a heart rate monitor (RS800CX; Polar Electro Oy, Kempele, Finland) was used to record the electrocardiogram R–R wave intervals (RRIs). The root mean square of successive differences (RMSSD) of RRI, the percentage of successive RRIs that differ by more than 50 ms (pNN50) for the time domain, the power of the high-frequency band (HF; 0.15–0.4 Hz) in normalized units (HFnu), the power of the low-frequency band (LF; 0.04–0.15 Hz) in normalized units (LFnu) for frequency domain, Poincaré plot standard deviation (SD) perpendicular to the line of identity (SD1), and Poincaré plot SD along the line of identity (SD2) for nonlinear valuables were calculated with Kubios HRV Premium software (ver.3.0.2; Kubios Oy, Kuopio, Finland).

Values of all parameters before stimulation were not significantly different between the three conditions. RRIs during stimulation were significantly longer for both mechanical and ice-cold stimuli than those obtained before stimulation ($p < 0.001$, $p = 0.004$, respectively). Differences in RRIs between before and during stimulation were significantly higher for mechanical stimulus (61.1 ± 16.9 ms, $p = 0.013$) and ice-cold stimulus conditions (63.1 ± 37.7 ms, $p = 0.01$) than for non-stimulus conditions (-0.9 ± 31.6 ms). In mechanical and ice-cold stimulus conditions, HFnu during stimulation increased significantly ($p = 0.036$ and $p = 0.011$, respectively), while LFnu decreased ($p = 0.036$ and $p = 0.011$, respectively). LF/HF during stimulation was significantly ($p = 0.043$) lower for ice-cold stimulus than before stimulation, while it tended to decrease for

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mechanical stimulus ($p=0.082$). SD2 was lower for both mechanical stimulus and ice-cold stimulus during stimulation than before stimulation ($p=0.006$ and 0.051, respectively). SD2/SD1 during stimulation was significantly lower for both mechanical and ice-cold stimulus conditions than before stimulation ($p=0.016$ and $p=0.006$, respectively). The difference in SD2/SD1 between before and during stimulation was significantly greater for ice-cold stimulus (-0.833 ± 0.645, $p=0.037$) than for non-stimulus (0.020 ± 0.393).

In this study, RRIs were significantly increased by non-invasive mechanical stimulus of facial skin with the elastomer roller, and the change was equivalent to that observed when ice-cold stimulus was applied to the same area. In analyzing heart rate variability, we found that HFnu, an indicator of vagus nerve activity [8], was significantly higher during stimulation than it was before stimulation. On the other hand, SD2/SD1—an indicator of sympathetic nerve activity [9]—decreased significantly. Based on these results, an increase in vagal activity and a decrease in sympathetic nervous activity caused by the roller-type mechanical skin stimulation were considered to result in an increase in RRIs.

It has been reported that the same tools used in this study increase the activity of low-threshold mechanoreceptive C fibers (6) and these fibers are contained in the terminal branches of the human trigeminal nerve (7). These studies suggest that mechanical stimulus of a skin surface by this roller tool may have excited low-threshold mechanoreceptive C fibers in human trigeminal nerves. As a result, the trigeminal-vagal nerve reflex observed in facial cooling and ocular compression stimuli [10] may have occurred.

Mechanical stimulus increased RRIs by 61 ms. Patients with essential hypertension are reported to have RRIs at rest that are 55 ms shorter than those of healthy controls [3]. Therefore, mechanical stimulus may be effective in stimulating vagus nerve reactivity of patients with vagal suppression. When hypertensive patients took 6 breaths/min, their baroreflex sensitivity increased, although RRIs did not change [3]. This effect was seen not only in hypertensive patients but also in healthy controls [3]. Our results were obtained from healthy subjects, but it appears reasonable that similar results could be expected for patients with vagus nerve suppression. However, the effects of mechanical stimulus in this study were short-lasting and the sample size was small. Future studies should examine the long-term effects in a large number of subjects with vagus nerve suppression.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study protocol was approved by the Ethics Committee of Tokoha University (2017-012H) and has been performed in accordance with the 1964 Declaration of Helsinki and its later amendments.

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